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Evaluation of the Development Impacts from CIF's Investments

Case Studies

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Climate Investment Funds

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1. Bangladesh Light-Touch Case Study: Catalyzing the Industrial Rooftop Solar Market

Project Details	Funding
Name: Scaling Up Renewable Energy **Country:** Bangladesh **CIF Program Area:** Scaling-up Renewable Energy Program in Low-Income Countries (SREP) **Bank approval:** March 2019 **Effective since:** December 2019 **Expected closing:** July 2025 **MDB:** World Bank	**Total Value:** $413.04 million **CIF:** $29.25 million **Co-financing:** $383.79 million **MDB:** $156 million **Government of Bangladesh:** $48.79 million **Bilateral agencies:** $179 million **Instrument type:** Loan, grant **Sector:** Public

Key Highlights

- The Bangladesh Scaling up Renewable Energy Project (Bangladesh SREP Project) is a $413.04 million investment in renewables.
- The CIF contribution is $26.38 million in loans and $2.87 million in grants. The remaining $383.79 million was funded by a World Bank International Development Association (IDA) loan of $156 million, $48.79 million from the Government of Bangladesh, and $179 million through bilateral agencies, including $120 million in commercial financing/private capital mobilized.
- This case study focuses on industrial rooftop solar funded in part through SREP.

Topline Findings on Development Impacts

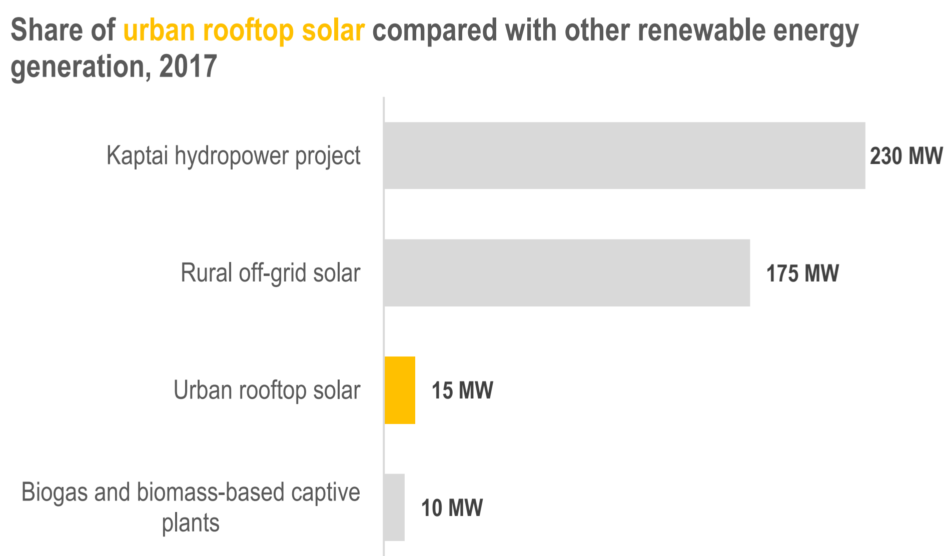
- **Market growth:** Twenty-three rooftop solar PV projects have been approved to date, with a combined capacity of 80 MW.
- **Employment:** The project has employed approximately 153 people to date, with a total of 334 jobs expected by December 2021, and 1,978 jobs forecast for approved projects.
- **Bill savings:** Average on-bill savings for factory owners is estimated at $1,700 per year. Adding storage to existing solar installations has the potential to unlock extensive on-bill savings, especially for factories that run during peak demand evening hours.
- **Other DIs:** Additional benefits include reduced diesel generator use and reduced criteria air pollution and greenhouse gas (GHG) emissions, a more reliable electricity supply for the country's largest industrial sector, and decreased reliance on imported fossil fuels.
- Long-term benefits could include increased competitiveness of the sector, improved working conditions, and improved health and quality of life benefits.

Climate Investment Context and Overview

Bangladesh is one of the world's most densely populated countries, with about 171.2 million residents as of 2022, or 1,315 per square kilometer, almost nine times the Asian average.[1] The country's rapid development has increased demand for electricity, transport, and telecommunication services. Access to electricity expanded from less than 50 percent in 2007 to about 76 percent in 2017.[2] Between 2009 and 2016, Bangladesh's power generation capacity more than doubled, from 3,000 MW to 8,000 MW, mainly through the construction of gas-fired power plants. However, electricity demand still exceeds the supply, and there are frequent power interruptions, particularly in rural areas. During peak demand hours, when blackouts are common, industries often rely on expensive and polluting diesel generation.

Bangladesh has significant renewable energy potential, but as of 2017, the share of renewables on the grid was only 1.5 percent, and total renewable energy generation capacity was only 430 MW (see Figure 1).[3] This included 230 MW from the Kaptai hydropower project, the only grid-connected renewable resource; 175 MW of off-grid solar in rural areas; 15 MW of rooftop solar in urban areas; and about 10 MW in biogas and biomass-fired captive plants. Solar generation has grown rapidly since then, reaching 715 MW in 2022, out of a total of nearly 950 MW of installed renewable capacity.[4] Resource estimates indicate potential for an additional 3,700 MW, including 2,600 MW of ground-mounted solar and wind and rooftop solar.[5]

Figure 1. Installed Renewable Energy Generation Capacity as of 2017



The Bangladesh Scaling-up Renewable Energy Project is a $413.04 million investment to increase renewable generation capacity across the country. The project, which was approved in 2019, has three components:[6]

1. Utility-scale solar development of the Feni Utility-Scale Solar PV renewable energy park, which began with a 50 MW pilot and will eventually support 150–170 MW of solar. The pilot is expected to be increased to 75 MW with the benefit of significant project savings achieved in the initial 50 MW phase (**$89.17 million**).

2. The establishment of a dedicated Renewable Energy Financing Facility (REFF) within a financial intermediary, the Infrastructure Development Company Limited (IDCOL). The REFF is used to make loans and provide technical assistance to support a variety of renewable energy projects, ***including rooftop solar***. The goal of the REFF is to support 200 MW of installed capacity; the initial target for rooftop solar PV on industrial buildings was 30 MW. This component will also provide some capacity building and market development support to IDCOL (**$320.23 million**, including $26.38 million CIF SREP loan).

3. Technical assistance and capacity building to improve the business and regulatory environment by supporting resource and feasibility assessments, promoting and strengthening regulatory policies for scaling up a rooftop solar market, providing training for government agencies, supporting small-scale pilots of renewable energy technologies—including a waste-to-energy pilot—and supporting Sustainable and Renewable Energy Development Authority (SREDA) project management activities (**$3.64 million**, including $2.87 million CIF SREP grant).

Project objectives related to CIF financing

CIF contributed about 7 percent of **Error! Bookmark not defined.**the project's total value: $26.38 million in loans and $2.87 million in grants. The World Bank provided a $156 million loan through the International Development Association (IDA), which amounts to 38 percent of the total project value. The remaining $227.79 million comes from the Government of Bangladesh ($48.79 million) and bilateral agencies ($179 million).[7]

As noted above, CIF's SREP loan funds were invested in Component 2, which established the REFF, and the REFF funded rooftop solar projects. The project's target for installing rooftop solar on industrial buildings was 30 MW.[8] This case study focuses on the REFF's rooftop solar implementation because it is currently the most advanced component, allowing for the examination of development impacts. It is important to note that this case study was conducted in December 2021; except as explicitly noted otherwise, all information is current as of then.[9]

Another SREP project in Bangladesh was launched in 2017 with the International Finance Corporation (IFC): Off-Grid Solar PV: Solar Irrigation, with an estimated cost of $22.22 million.[10] However, like the other components of the Bangladesh SREP Project, the solar irrigation project requires more time for implementation before results can be analyzed, so it is not included in this case study.

Project stakeholders

The key stakeholders for this project include the Government of Bangladesh and the project's implementing agencies, the Electricity Generation Company of Bangladesh (EGCB), the Infrastructure Development Company Limited (IDCOL), the Sustainable and Renewable Energy Development Authority (SREDA), the solar development industry, and the ready-made garment (RMG) industry. The EGCB is the state-owned generation utility, primarily involved in the Feni renewable energy park component of the project. IDCOL is a state-owned financial institution that houses and manage the REFF and provides early screening of projects prior to the World Bank due diligence process. SREDA is implementing the resource assessment and waste-to-energy pilot components of the project and is also responsible for Bangladesh's SREP program overall.[11]

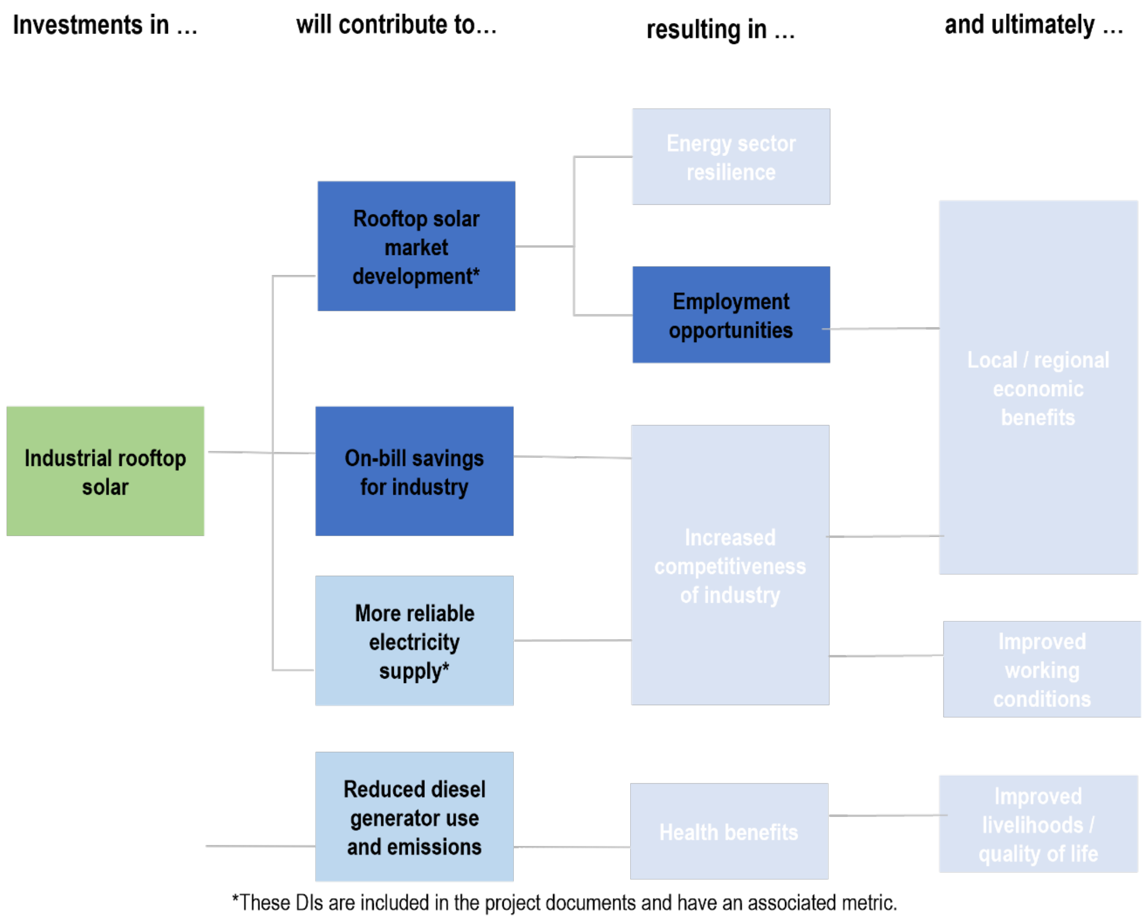
Development Impact Pathways and Case Study Focus

The purpose of this case study is to analyze the development impacts (DIs) of SREP's investments in scaling up grid-connected industrial rooftop solar at RMG factories in Bangladesh. The main goal of SREP Component 2 is to offer specialized financial products to address the finance constraints of public-private partnerships (PPP) and private sector developers[12] to support the development of renewable energy subprojects through the REFF. Specifically, the REFF has worked to finance grid-connected rooftop solar on industrial rooftops—to date, mainly for RMG factories. The REFF also aims to add solar to the roofs of government and institutional buildings. The project's strategy is to set the cost and tenor of REFF-provided financing options, such that the levelized cost of rooftop solar, at less than the retail price of electricity, incentivizes private sector investment in the technology.[13]

Figure 2 illustrates the impact pathways for rooftop solar in Bangladesh's RMG sector. The dark blue boxes indicate the DIs that were quantified in this case study: rooftop solar market development, on-bill savings for industry, and employment opportunities. The light blue boxes indicate the DIs that were qualitatively assessed: more reliable electricity supply and reduced generator use and emissions. The gray boxes indicate DIs that could be realized through this investment impact pathway, but were not assessed for one or more reasons, such as expected timeframe of impact, scale of the project, or additional research and analysis requirements. Specifically:

- **Regional economic benefits:** would require additional analysis including modeling. The scale of the project also may currently be too small to assess this DI.
- **Increased competitiveness of industry** (and potential subsequent benefit of improved working conditions): would require additional research to understand if rooftop solar is improving competitiveness of the RMG industry. It may also be too soon to study this DI.
- **Energy sector resilience:** the scale of the project would need to be larger to affect the overall functioning of the power sector in Bangladesh.
- **Health impacts** (and subsequent quality-of-life impacts): would require extensive original analysis to assess health impacts from improved air quality related to increased use of rooftop solar, and decreased use of on-site diesel generators and/or reduced reliance on fossil fuel-generated utility power.

Figure 2. Impact Pathway for Rooftop Solar in RMG Sector in Bangladesh



Two of the DIs identified in our impact pathways are mentioned in the project approval documents for the rooftop solar component: market development and energy supply reliability. The applicable metric for market development in project approval documents is "[volume of] investment mobilized for renewable energy generation capacity," specifically funding mobilized by the REFF from other sources. The target is $212 million, of which $4.9 million had been mobilized as of September 2021. We note that market development is also evident in solar developers having increased access to affordable capital. The official metric for energy supply reliability is "share of end-users expressing satisfaction with rooftop PV systems due to the improvement in electricity service," with a target of 75 percent.

Development Impacts: Performance to Date

This project was approved by the World Bank in March 2019 and became effective in December 2019. As of September 2021, about 3 percent of the IDA loans and CIF contribution had been disbursed. Though implementation is underway, the project has seen some delays due to the COVID-19 pandemic. The project was originally set to close in January 2024, but has been extended until July 31, 2025.[14] Table 1 provides an overview of the DIs quantified in this section and the metric and method of assessment.

Table 1. Development Impacts Assessed Quantitatively in this Case Study

DI	Included in original project documents?	Metric /KPI	Method of assessment
Industrial rooftop solar market development	Yes	Volume and amount of financing mobilized	Project progress reports
Employment opportunities (job creation)	No	Direct rooftop solar installation/maintenance FTEs	Quantitative analysis using jobs factors from India
On-bill savings for ratepayers (e.g., RMG factories)	No	Average $ value of on-bill savings	Quantitative analysis via data collected from interviews

Market development

As of September 2021, IDCOL had approved a total of 23 rooftop solar PV subprojects for REFF financing, expected to add 80 MW of generation capacity. Five projects totaling 6.17 MW were already operational, and an additional four projects were expected to be completed by December 2021, bringing the total added installed capacity to 13.5 MW.[15] The total budget for the REFF is $320.23 million, and it aims to de-risk investments and to mobilize additional private sector investment.[16] The accessibility of finance is building a functioning solar market supported by growing outside investment (approximately $4.9 million in external funding as of September 2021)[17] to increase renewable energy generation capacity. According to an expert interview, about half of new rooftop solar projects at industrial sites in the country are financed through the REFF.[18] Thus, we estimate that there are approximately 46 new industrial rooftop solar projects with total estimated installed capacity of 160 MW operational or soon-to-be operational that have been catalyzed by the project.

In April 2021, SREDA and the Bangladesh Garment Manufacturers and Exporters Association (BGMEA) signed a memorandum of understanding (MOU) under which SREDA will help the garment industry to install solar panels (potentially through the REFF). In addition, the organizations agreed to coordinate to raise awareness about renewable energy in the RMG sector and pursue funding together. An IDCOL representative stated factories with a lower carbon footprint are more competitive in the global market, which can lead to improved business and thus better wages and welfare for workers.[19] The government's continued support of the industry though accessible finance and favorable policy solutions could contribute to further development of the rooftop solar industry in Bangladesh and increase clean energy deployment in the RMG sector.[20] However, the full effects of these policy actions were not comprehensively researched as part of this case study.

Employment opportunities

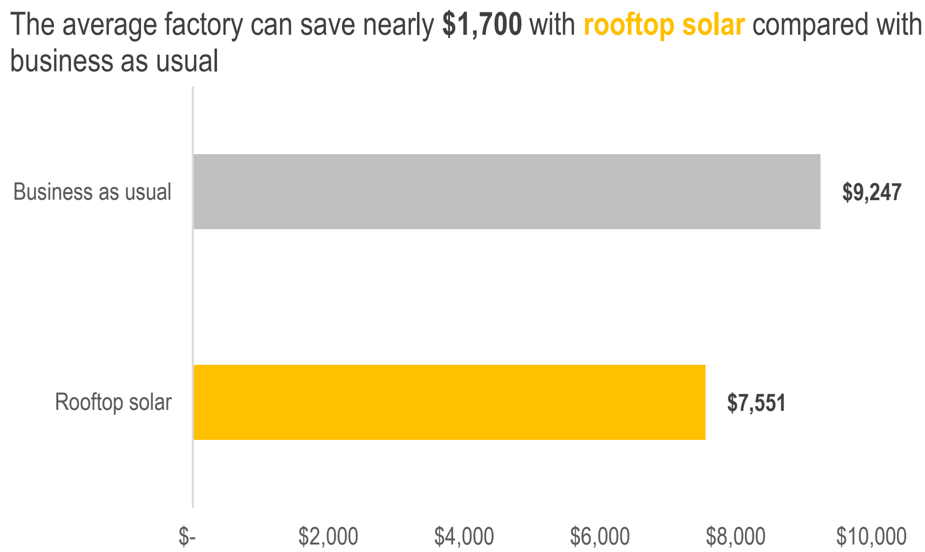
We did not find literature on job creation associated with rooftop solar in Bangladesh in particular. However, a study in India found that rooftop solar employed 24.72 FTEs[21] in installation and operation per MW of installed capacity per year.[22] This analysis is likely the best proxy for job impacts in Bangladesh. Applying that figure to the 23 projects underwritten by the REFF in Bangladesh, we estimate that the project has employed about 153 people to date, with a total of 334 jobs expected by December 2021, and 1,978 jobs forecast for all 23 approved projects. The growth in rooftop solar can create additional employment across the manufacturing, engineering, and operation and maintenance sectors of the solar industry. IDCOL is also evaluating an additional eight utility-scale PV projects that would add another 536 MW of renewable energy capacity. However, the implementation timeline for these projects is uncertain due to land acquisition issues.[23] If all 46 projects catalyzed by the Bangladesh SREP project become operational, with an increased capacity of 160 MW, they would generate about 3,955 jobs in total.

We expect that women would be employed in many of these jobs. A global study by the International Renewable Energy Agency (IRENA) shows that the share of women working in full-time positions in the solar PV industry is 40 percent, which is almost double the share in the wind industry (20 percent) and oil and gas sector (22 percent) and higher than the share of women working across the entire renewable energy landscape (32 percent). Of the solar PV jobs employing women, manufacturing has the highest share of women (47 percent), followed by service providers (39 percent) and developers (37 percent).[24]

On-bill savings

An estimated 8,000 facilities[25] produce ready-to-wear garments in Bangladesh; this is a key industrial sector for the country. RMG factories are quite large and have extended rooftops that are well suited to rooftop solar.[26] An IDCOL representative said in an interview that by installing rooftop solar, factories can save approximately 2 Bangladeshi Taka (BDT)/$0.0234 per kWh.[27] Rooftop solar costs 6.5–6.7 BDT/$0.0770 cents per kWh, when factoring in the cost of the loan and the lifetime of the rooftop systems. This is compared with off-peak grid electricity, which costs 8.09 BDT/$0.0943.[28] Using estimates of per unit energy consumption in the clothing industry[29] and data from the Bangladesh Knitwear Exporters and Manufacturers Association (BKMEA),[30] we estimate that each RMG factory uses 68,910–127,219 kWh of electricity per year, or an average of 98,064 kWh. Thus, installing rooftop solar results in savings of approximately $1,700[31] per year for the average factory (see Figure 3). Installing energy storage in addition to rooftop solar would help factories derive even more value from solar installations, as they could store electricity captured during off-peak hours, and use that energy in the near future and/or during the expensive peak period.[32]

Figure 3. Comparison of Electricity Costs for RMG Factories with and without Rooftop Solar



Other Implied DI Benefits (Not Assessed)

As noted above, it is reasonable to expect some additional DIs to be realized through this project, but it is either too soon to assess them, the scale of the project does not lend itself to such an assessment, or additional research and analysis would be needed. This section provides a brief overview.

Reduced emissions and energy cost savings from avoided diesel generator use

Because of reliability problems, Bangladeshi RMG factories often operate on diesel generators.[33] Diesel generators are an expensive source of electricity and significant sources of GHG emissions and air pollution. Factories that install rooftop solar can reduce or eliminate their reliance on these generators, saving money, reducing GHG emissions, and avoiding air pollution from the generators, which would also be beneficial for human health.

Energy security

Increased use of rooftop solar decreases the country's reliance on imported fossil fuels and improves its trade balance.[34]

Enabling Conditions and Barriers to Realizing DIs

EPC contractor development

According to experts interviewed, there are currently only five or six high-quality solar EPC (engineering, permitting, and construction) contractors operating in Bangladesh, which speaks to limited technical and commercial capacity in the sector.[35] Some of these firms have recently formed or formalized in response to the project and, more generally, the growing demand for rooftop solar. The lack of EPC contractors and limited workforce development was originally a barrier to the uptake of rooftop solar. Despite the significant growth in the past few years, additional local EPC firms and workforce development would be helpful in scaling up the industry to meet the increasing demand for rooftop solar.

Net metering

There was no net metering scheme[36] in Bangladesh when the project was conceptualized in 2017. The government approved Net Energy Metering Guidelines in July 2018.[37] According to interviewees, net metering is key to unlocking the cost-savings potential of rooftop solar for the RMG industry. Current net metering guidelines cap the maximum amount of rooftop electricity export to the grid at 70 percent of consumption/import of grid electricity for the same connection,[38] which limits the producer's maximum power generation.[39] **Error! Bookmark not defined.**Some stakeholders indicate that the guidelines do not incentivize business participation enough to achieve scale up. Originally, the lack of net metering was a significant barrier to installing rooftop solar. Though some barriers remain and the policy is still new, the guidelines provide significant support to the developing rooftop solar sector.

Other barriers to scaling up rooftop solar and realizing DIs

Scale up of industrial rooftop solar is a prerequisite for attaining potential longer-term DIs that can result from the growth of this sector, such as increased RMG industry competitiveness, improved labor conditions, and regional economic benefits. Several barriers to scale up remain, despite recent progress:

- Project development challenges and financing challenges have hindered development of the sector due to limited capacity, funding, and regulatory support.
- Rooftop solar is not going to be a financially viable solution for some factories and some sites. The economics of the installations are variable depending on the orientation of the facility, the cost of the panels, the cost of labor to install, and the financing cost.
- Bangladesh has an older distribution network, which can lead to problems with implementing net metering and injecting power into the grid from distributed resources.
- Solar is an intermittent generation source, not dispatchable like diesel generators, so it cannot be relied on to fill supply gaps in the event of a power interruption, as its availability is determined by the time of day, weather, and electricity demand.[40]
- Current lack of battery storage: The use of rooftop solar is not optimized for factories that run multiple shifts because in such cases peak demand occurs during the night shift when panels are not producing electricity.[41] The price of battery storage has been prohibitively expensive, but that is quickly changing, as described below under Future Opportunities.
- Basic energy efficiency measures are sometimes overlooked by factory owners. Efficiency measures should be deployed alongside or prior to the installation of renewables to decrease energy use and maximize savings.
- Administrative requirements to receive financing through the REFF can be a barrier, although efforts have been made to streamline the process.[42] Given the complex process, several industrial solar projects sought commercial financing, which can be more expensive.
- Government and institutional buildings, such as universities, were also noted as candidates for rooftop solar in project documents, but this aspect of the project has not been realized because the current tariff structure does not make rooftop solar financially attractive. There are limited incentives from government policy to change this.[43]

Future Opportunities for Realizing DIs through Rooftop Solar

Scale-up potential

There is significant room for scaling up rooftop solar in Bangladesh, even just with the project's initial focus of industrial rooftops alone, considering that there are over 8,000 RMG factories in Bangladesh. Moreover, solar potential is not limited to RMG factories. The number of approved solar rooftop projects becoming operational is also growing quickly, so there is momentum in the right direction. One expert noted that Bangladesh has ambitious plans to develop 100 economic zones by 2035, which are private areas of 650 square kilometers, with significant scope for rooftop systems.[44] Incentivizing or mandating rooftop systems, while providing concessional funding, would be an effective vector for scale up. As more RMG factory solar installations become operational, and the benefits from cheaper and more reliable power are realized, there may be an increase in demand for rooftop solar from both the RMG industry and other industries. This will lead to further de-risking and growth of outside investment.

Promise of storage

The cost reduction trend in battery energy storage represents a near future opportunity to improve the economic rationale for factory owners to install solar. This has the potential to accelerate industrial rooftop solar scale up, and subsequently realize broader DIs. Due to investments in battery technology, largely due to the popularity of electric vehicles, Bloomberg New Energy Finance estimates that batteries will cost $100 per kWh by 2025, which is a key threshold for affordability.[45] Once battery systems can be added to rooftop solar installations affordably, factories that run multiple shifts can avoid demand charges during peak hours, which often constitute the majority of electricity costs for industrial facilities that have multiple shifts. Even for facilities that run single shifts, using batteries to store excess power generated during the day for future use can increase on-bill savings relative to using net metering to sell excess power back to the grid. Installing storage may also significantly reduce the need to install and use diesel generators to ensure electricity reliability.

RMG sector economic, environmental, and social sustainability

Embracing rooftop solar is also consistent with the RMG sector's efforts to improve the sustainability of its operations. Production costs in the apparel sector have increased due to investments in technology and safety, and an increase in wages. In addition, the industry's export goals are growing, putting a strain on production capacity. Efficiency improvements in the use of labor, materials, and resources can help meet these demands.[46] Adopting rooftop solar as a strategy can provide cost savings to factory owners, as well as environmental benefits and reputational benefits.

Consumer awareness of the high resource intensity of garment production has risen in recent years, which has led to an interest in environmentally friendly clothing and pressure within the RMG sector to adopt better environmental initiatives.[47] The industry is aware of the importance of environmental sustainability and is working with the government and other private sector actors to improve its performance. BGMEA is one of the largest trade bodies in the Bangladesh RMG industry with approximately 4,500 member factories. According to BGMEA, there are currently 150 LEED-certified garment factories in Bangladesh, with another 500 factories in the process of becoming certified. BGMEA has also signed the UN Fashion Industry Charter for Climate Action to help reduce the fashion industry's GHG emissions by 30 percent by 2030 and to set a decarbonization pathway for the industry. The organization has also joined initiatives to improve sustainability such as Germany's Green Button

Initiative and Phase 2 of France's Fashion Pact. Finally, BGMEA is involved with several policy initiatives with the Government of Bangladesh, such as developing guidelines for Green Economic Zones and efforts to improve water resource management and waste management.[48] Considering that Bangladesh is one of the world's leading apparel exporters, these sustainability efforts have the potential to impact the country's carbon emissions. Bangladesh's RMG industry may become more globally competitive if there is wholesale buyer awareness and/or public awareness of its use of rooftop solar.

There has also been significant international interest in Bangladesh's RMG industry due to a history of workplace safety issues and disasters, including most notably the Rana Plaza collapse in 2013, which was catalyzed by vibrations from diesel generator use.[49] The government's push to improve building and fire safety after the disaster was met with reluctance from factory owners due to limited financing options and high interest rates on loans. This was abated in part by IFC funding and concessional credit specifically to make improvements that addressed workplace safety issues. Around the same time, IFC launched its Partnership for Cleaner Textile, or PACT, in 2013, to help the garment sector reduce water and energy use.[50] IFC financing has thus played a large role in improving both safety issues and environmental concerns for the garment industry.

There are some connections between environmental sustainability considerations and workplace safety considerations within the industry. Safety concerns may contribute to the willingness of the RMG industry to make efficiency improvements, such as adopting rooftop solar. Building structures and roofs need to be strong enough to support panel installation. At the same time, this industry may be wary of potential safety issues with unfamiliar on-site power generation and the use of inverters, which may pose a barrier to solar adoption, unlike in other industries in Bangladesh that are not facing as much scrutiny. In 2019, BGMEA signed an MOU to improve livelihoods for one million RMG employees while also making progress towards the following Sustainable Development Goals (SDGs): SDG 3: Good Health and Wellbeing, SDG 5: Gender Equality, SDG 6: Clean Water and Sanitation, SDG 12: Responsible Consumption and Production, and SDG 17: Partnerships to achieve the Goal.[51] However, beyond this high-level MOU, it is not clear if the RMG industry is coordinating clean energy and worker safety initiatives. There is potential for rooftop solar installations to make the sector more competitive economically, and the resulting cost savings could be invested in workplace safety efforts. BGMEA and the RMG industry's growing focus on sustainability is relatively new, and actions are voluntary with no enforcement mechanisms. There is room for increased coordination and oversight, whether by BGMEA or another industry player.

Future SREP projects

The Bangladesh SREP Project's model of rooftop solar support could be replicated anywhere with similar conditions: an appropriate climate, an industrial sector that can readily benefit from cheaper and more reliable power, government willingness to adopt a net metering tariff, and existence or establishment of a lending organization that can offer concessional finance. CIF should consider having future SREP projects using this model track market development, employment, and on-bill savings metrics used in this case study. CIF may also want to consider tracking avoided diesel use, if the industry installing rooftop has some reliance on diesel generators. This would also enable estimation of health benefits.

Future research

CIF and its partners should consider additional research to facilitate analysis of DIs associated with industrial rooftop solar installation in Bangladesh and elsewhere. In particular, we recommend studying:

- Impacts of solar installation on **reducing diesel use,** avoiding fuel costs, and potentially avoiding the need for investment in generators for solar, or investing in storage projects. In addition, reducing diesel avoids criteria pollutant emissions (in addition to avoiding GHG emissions), and avoiding criteria pollutants can improve overall air quality and potentially avoid health impacts. However, estimating changes to local air quality and attendant health impacts would require extensive additional research and analysis, and may not find overall health benefits. Bangladesh is still heavily investing in increasing electricity generation capacity through building new fossil fuel generating units, and the country has other drivers of air quality challenges such as mobile source pollution. It is not clear whether diesel generator use is a measurable driver of overall air quality. As such, a scoping analysis would be recommended to understand the potential for health impact benefits, prior to conducting a full analysis of this potential DI area.
- **Regional economic benefits,** including economic output and increased wages associated with REFF-funded rooftop installations, current and future, as well as rooftop solar projects associated with SREP-funded projects (e.g., a REFF-funded solar developer subsequently using conventional financing, or a factory owner of a REFF-funded project subsequently using conventional financing for installations at other factories). This analysis would require additional data collection and modeling.
- Analysis of **industrial competitiveness** of the country's garment factories and the role of rooftop solar in influencing competitiveness. This analysis would require extensive research and interviews with garment factory owners/operators who have or have not installed solar.
- **Impacts specific to women:** Considering that the majority of garment industry employees are women, improvements to worker safety and attendant quality of life benefits should proportionately benefit women. This analysis would require additional research and data collection on potential connections between worker safety initiatives and rooftop solar; for example, the same factory owners may be likely to invest in both. The analysis would also require interviews with factor owners/operators and workers.

Table 2. Interviewee List

Organization	Designation	Name
World Bank	Sr. Environmental Specialist	Jari Vayrynen
SREDA	Assistant PD	Tanvir Masud
SREDA	Member (JS), EEC, SREDA	Farzana Momtaz
	Director (JS), RE	Mohammad Kainat
IDCOL/REFF	Head of RE	Enamul Karim (Pavel)
	Unit Head, RE	Farzana Rahman
	VP of Monitoring, RE	Kazi Absan Uddin

KfW	Portfolio Manager	Mareike Shamel
KfW	Deputy Director	Tazmilur Rahman
BUET and SREDA	Professor	Ziaur Rahman Khan
UIU Centre for Energy Research	Assistant Professor and Director	Shahriar Ahmed Chowdhury
Tusuka Group	RMG Factory Owner	Arshad Jamal
BSREA	President	Dipal Barua

[1] Custom data obtained online from UN DESA. 2022. "World Population Prospects 2022." New York: United Nations Department of Economic and Social Affairs, Population Division. http://esa.un.org/unpd/wpp/.

[2] World Bank, *Project Information Document/Integrated Safeguards Data Sheet for Bangladesh Scaling-up Renewable Energy Project*, May 2017, available at: https://pubdocs.worldbank.org/en/164441531554963089/5246-XSREBD076A-Bangladesh-Project-Document-PID.pdf

[3] Ibid.

[4] SREDA, National Database of Renewable Energy, updated November 28, 2022, available at http://www.renewableenergy.gov.bd.

[5] Ibid.

[6] People's Republic of Bangladesh and International Development Association, *Financing Agreement: Bangladesh Scaling-Up Renewable Energy Project*, 2019, available at: https://documents.worldbank.org/en/publication/documents-reports/documentdetail/147381568309655518/official-documents-financing-agreement-for-credit-6363-bd-closing-package

[7] World Bank, *Bangladesh Scaling-up Renewable Energy Project: Finances*, 2021, available at: https://projects.worldbank.org/en/projects-operations/project-detail/P161869

[8] World Bank, *Project Information Document/Integrated Safeguards Data Sheet for Bangladesh Scaling-up Renewable Energy Project*, May 2017.

[9] For the latest project updates, see the project page on the World Bank website: https://projects.worldbank.org/en/projects-operations/project-detail/P161869.

[10] World Bank, Cover Page for Project/Program Approval Request for Power System Efficiency Improvement Project – Additional Financing (Off-grid solar PV: solar irrigation), February 2013, available at: https://pubdocs.worldbank.org/en/657811531554941018/4102-XSREBD064A-Bangladesh-Cover-Page-and-Project-Document.pdf

[11] World Bank, *Project Information Document/Integrated Safeguards Data Sheet for Bangladesh Scaling-up Renewable Energy Project*, May 2017.

[12] People's Republic of Bangladesh and International Development Association, *Financing Agreement: Bangladesh Scaling-Up Renewable Energy Project*, 2019.

[13] World Bank, *Project Information Document/Integrated Safeguards Data Sheet for Bangladesh Scaling-up Renewable Energy Project*, May 2017.

[14] See project page on the World Bank website: https://projects.worldbank.org/en/projects-operations/project-detail/P161869.

[15] World Bank, *Disclosable Version of the ISR – Bangladesh Scaling-up Renewable Energy Project – P161869 – Sequence No : 05 (English)*, September 2021, available at: https://documents.worldbank.org/en/publication/documents-reports/documentdetail/425511631555847925/disclosable-version-of-the-isr-bangladesh-scaling-up-renewable-energy-project-p161869-sequence-no-05. Since the time of writing, seven projects with a total capacity of approximately 12 MW were already operational as of October 2022, according to the October 2022 ISR: https://documents1.worldbank.org/curated/en/099005010192224292/pdf/P161869076c8b60e909557082b4afe692cf.pdf.

[16] World Bank, *Project Information Document/Integrated Safeguards Data Sheet for Bangladesh Scaling-up Renewable Energy Project*, May 2017.

[17] World Bank, *Disclosable Version of the ISR – Bangladesh Scaling-up Renewable Energy Project – P161869.*

[18] Expert interview, December 13, 2021.

[19] Written communication from IDCOL representative, November 4, 2021.

[20] UNB News, *SREDA, BGMEA sign deal for rooftop solar power promotion in RMG sector*, The Business Post, April 2021, available at: https://businesspostbd.com/post/15872

[21] The study used data collected from official sources to calculate employment coefficients as FTE jobs/MW/year, which normalizes employment variations between the construction phase and operation and maintenance phase. The employment coefficients account for the entire technology value chain, incorporating both direct and indirect jobs.
[22] Cobenefits, *Future skills and job creation with renewable energy in India*, October 2019, available at: https://www.ceew.in/sites/default/files/CEEW-%20COBENEFITS-Study-India-Employment%2031Jan20.pdf
[23] World Bank, *Disclosable Version of the ISR – Bangladesh Scaling-up Renewable Energy Project – P161869.*
[24] IRENA, *Solar PV: A Gender Perspective*, September 2022, available at: https://www.irena.org/publications/2022/Sep/Solar-PV-Gender-Perspective
[25] There are some discrepancies regarding the number of RMGs in Bangladesh. In 2017, there were an estimated 3,778 factories enrolled in the Alliance for Bangladesh Worker Safety, the Accord on Fire and Building Safety in Bangladesh, and the National Tripartite Plan of Action on Fire Safety and Structural Integrity in the Garment Sector of Bangladesh. However, a more recent study by the BRAC University's Centre for Entrepreneurship identified over 8,000 facilities in the industry. See Tara Wadhwa, *Determining the True Cost of Remediating Bangladesh's RMG Sector*, NYU Stern Center for Business and Human Rights, September 7, 2017, available at: https://bhr.stern.nyu.edu/blogs/2017/9/7/determining-the-trust-cost-of-remediating-bangladeshs-rmg-sector
[26] World Bank, *Project Information Document/Integrated Safeguards Data Sheet for Bangladesh Scaling-up Renewable Energy Project*, May 2017.
[27] All values are approximate. Currency conversions as of November 18, 2021.
[28] Written communication from IDCOL representative, November 4, 2021.
Multiple interviewees provided consistent tariff information. The peak period is set by the Bangladesh government at between 5 pm and 11 pm daily. We use an off-peak rate for this analysis because 1) many factories run day shifts only and do not operate during the peak period and 2) solar panels generally do not generate power used during the peak period. See ADB Institute, *Role of Captive Power Plants in the Bangladesh Electricity Sector*, March 2021, page 8, available at: https://www.adb.org/sites/default/files/publication/692451/adbi-wp1238.pdf
[29] Ahmet Cay, *Energy consumption and energy saving potential in clothing industry*, *Energy*, 159, 74-85, September 2018, available at: https://doi.org/10.1016/j.energy.2018.06.128
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[31] Savings is 145,643 BDT/$1,696 per year.
[32] Expert interview, December 13, 2021.
[33] Shavon Islam, CEO and Manager of Sparrow Group of Industries, RMG Orders and Exports have gone up. So have challenges, Op-ed in *The Business Standard*, September 27, 2021, available at: https://www.tbsnews.net/features/panorama/rmg-orders-and-exports-have-gone-so-have-challenges-308002. And Tara Wadhwa, *Determining the True Cost of Remediating Bangladesh's RMG Sector*, NYU Stern Center for Business and Human Rights, September 7, 2017, available at: https://bhr.stern.nyu.edu/blogs/2017/9/7/determining-the-trust-cost-of-remediating-bangladeshs-rmg-sector
[34] Ibid.
[35] Expert interview, September 10, 2021.
[36] Net metering is a billing mechanism that credits solar energy producers for the energy they send to the grid.
[37] Shahriar Ahmed Chowdhury and Md. Ziaur Rahman Khan, *The Net Metering Guideline of Bangladesh-Potential and Way Forward*, *11th International Conference on Electrical and Computer Engineering (ICECE)*, 2020, available at: https://ieeexplore.ieee.org/document/9393148
[38] Expert interview, September 16, 2021.
[39] Shahriar Ahmed Chowdhury and Md. Ziaur Rahman Khan, *The Net Metering Guideline of Bangladesh-Potential and Way Forward*, *11th International Conference on Electrical and Computer Engineering (ICECE)*, 2020, available at: https://ieeexplore.ieee.org/document/9393148
[40] Expert interview, September 16, 2021.
[41] Expert interview, December 13, 2021.
[42] Expert interview, September 16, 2021.
[43] Expert interview, September 7, 2021.
[44] Expert interview, September 10, 2021.
[45] Sustainable and Renewable Energy Development Authority (SREDA), *Draft National Solar Energy Roadmap, 2021–2041*, December 2020, available at: https://industrialeconomics.sharepoint.com/sites/CIFSMME/Shared%20Documents/Case%20studies/Bangladesh/Bangladesh/SREP%20Bangladesh/Draft%20National%20Solar%20Energy%20Roadmap,%202021-2041.pdf
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[51] Apparel Resources News-Desk, Unilever partners with BGMEA to improve garment workers' lives, Apparel Resources, December 2019, available at http://apparelresources.com/business-news/sustainability/unilever-partners-bgmea-improve-garment-workers-lives/

2. Bangladesh Deep-Dive Case Study: Improving and Protecting Agricultural Livelihoods through Coastal Embankment Improvements

Project Details	Funding
Name: Coastal Embankment Improvement Project Phase 1 (CEIP-I) **Country:** Bangladesh **CIF Program Area:** PPCR **Bank approval:** June 2013 **Effective since:** November 2013 **Expected closing:** December 2023 **MDB:** World Bank	**Total Value:** $400 million **CIF:** $25 million **Co-financing (IDA):** $375 million **Instrument type:** Loan, grant **Sector:** Public

Key Highlights

- Of the total CEIP-I project value of $400 million, the CIF contribution was a $25 million grant, or about 6 percent of the total project's value. The remaining funds came through an International Development Association (IDA) concessional loan from the World Bank.
- Of the total CIF grant amount, $20 million is funding the rehabilitation and improvement of polders, which are tracts of low-lying land that are reclaimed from a sea or river and enclosed on all sides by dykes or embankments, separating them hydrologically from the main river system and offering protection against tidal floods, salinity intrusion, and sedimentation. The rest is funding long-term monitoring, research, and analysis of Bangladesh's coastal zone.
- According to interviewees, CIF's $5 million for long-term research was critical for securing stakeholder support for the CEIP-I project, as environmental groups opposed the overall project unless there was rigorous monitoring and evaluation (M&E).

Topline Findings on Development Impacts

- **Farmland protection:** Polder rehabilitation is protecting cropland from being regularly inundated by tidal flooding, which causes soil salinization and crop losses. For polders that have already been rehabilitated, storm surges have declined, as have community fears about storm surges.
- **Cropping intensity:** Cropping intensity is increasing by approximately 12 percent annually in the cooler Rabi season, and many farmers have introduced new profitable crops, including watermelon.[1] Cropping intensity in the other seasons has not increased due to several factors, including the need for re-excavation of canals and work on sluice gates to better control water flows and salinity.
- **Increased agricultural revenues:** Polder rehabilitation will increase overall agricultural revenue by providing protection from storm surges and riverine flooding, improving cropping intensity,

and enabling farmers to plant more profitable crops. According to crop revenue modeling, by 2032, polder rehabilitation will increase farmer revenues by an estimated $39–73 million per year, for an average of $56 million per year, compared with a business-as-usual scenario. This equates to approximately $90/hectare of benefits. The primary factors increasing revenues are storm surge protection, tidal flooding protection, and cropping intensity increase.

- **Regional jobs and economic impacts:** By 2032, nearly 25,000 jobs will be supported annually from the increase in agricultural revenues in the region. By 2032, the $56 million increase in annual agricultural revenues generates another $50 million per year in value added. This is made up of increased wages (41 percent), savings and profits (56 percent), and taxes (less than 4 percent).
- **Other DIs:** Additional benefits of CEIP-I include access to markets, general mobility, food security, and capacity-building benefits.

Climate Investment Context and Overview

Bangladesh is highly vulnerable to climate change due to its geography, with a large low-lying deltaic floodplain, the frequency of monsoon rainfall and extreme weather events, and socioeconomic conditions.[2] The country's average elevation is 4 to 5 meters above mean sea level. During heavy monsoons, about 70 percent of the country is flooded. The country's low-lying coastal zone is particularly vulnerable to cyclones, storm surges, and salinity intrusion.[3] Salinity intrusion contaminates the water supply,[4] decreases agricultural productivity,[5] and contributes to reducing the structural strength of pavements and the rusting of the reinforcement in concrete structures.[6]

Coastal embankment projects can help control water intake and drainage in polder areas, and thus support more intense crop production (i.e., denser plantings and increased yield) and agricultural growth.[7] The Government of Bangladesh began constructing embankments and polders in the 1960s; in the past 50 years, a total of 139 polders have been constructed. After a devastating cyclone in November 1970, the World Bank also began providing support for coastal area protection projects in the country.

Within the coastal embankment system of Southwest Bangladesh, 1.2 million hectares were used for agriculture in 2013, equivalent to about 15 percent of Bangladesh's total arable land.[8] The polders were initially constructed to protect against high tides, but strong cyclones damaged them over time. The polders also became waterlogged due to the siltation of surrounding rivers as well as poor maintenance and management. Prior to the launch of this project, waterlogging and increased salinity inside the polders were reducing soil fertility and agricultural production, affecting the livelihoods of local communities, who rely heavily on agriculture for sustenance and income.

Purpose and Scope of the Case Study

CIF's programmatic approach fosters collaboration among government ministries, civil society, Indigenous peoples, the private sector, and multilateral development banks (MDBs). In a country-led process, CIF works with these stakeholders to translate national development and climate strategies, including nationally determined contributions (NDCs) under the Paris Agreement, into a CIF action plan of long-term, sequenced investments that reinforce one another and link to other critical activities.[9]

This case study evaluates the development impacts (DIs) of coastal embankment rehabilitation in Southwest Bangladesh, with a focus on the myriad of economic and livelihood benefits resulting from agricultural land revitalization and protection. Specifically, this case study analyzes and forecasts the impact on agricultural revenues of increasing cropping intensity and protecting against storm surges and tidal flooding, as well as the regional economic effects. The case study also qualitatively explores improvements in food security, afforestation, coastal monitoring, national and local capacity building, and benefits to women and vulnerable populations. CIF aims to use the results to further optimize future programming, as lessons learned from this case study can help maximize DIs pertaining to climate change adaptation projects in other developing countries.

The Coastal Embankment Improvement Project (CEIP-1) is rehabilitating 10 polders in the coastal districts of Bagerhat, Khulna, Barguna, Patuakhali Pirojpur, and Jhalkathi and ensuring long-term maintenance and monitoring of the improvements.[10] CIF's Pilot Program for Climate Resilience (PPCR) contributed a US$25 million grant towards the total CEIP-I project value of $400 million, or about 6 percent of the project's total value.[11] The World Bank covered the rest through a $375 million concessional loan from the International Development Association (IDA). Table 1 below summarizes CEIP-I components. Sub-Appendix 1A provides additional details of budget components.

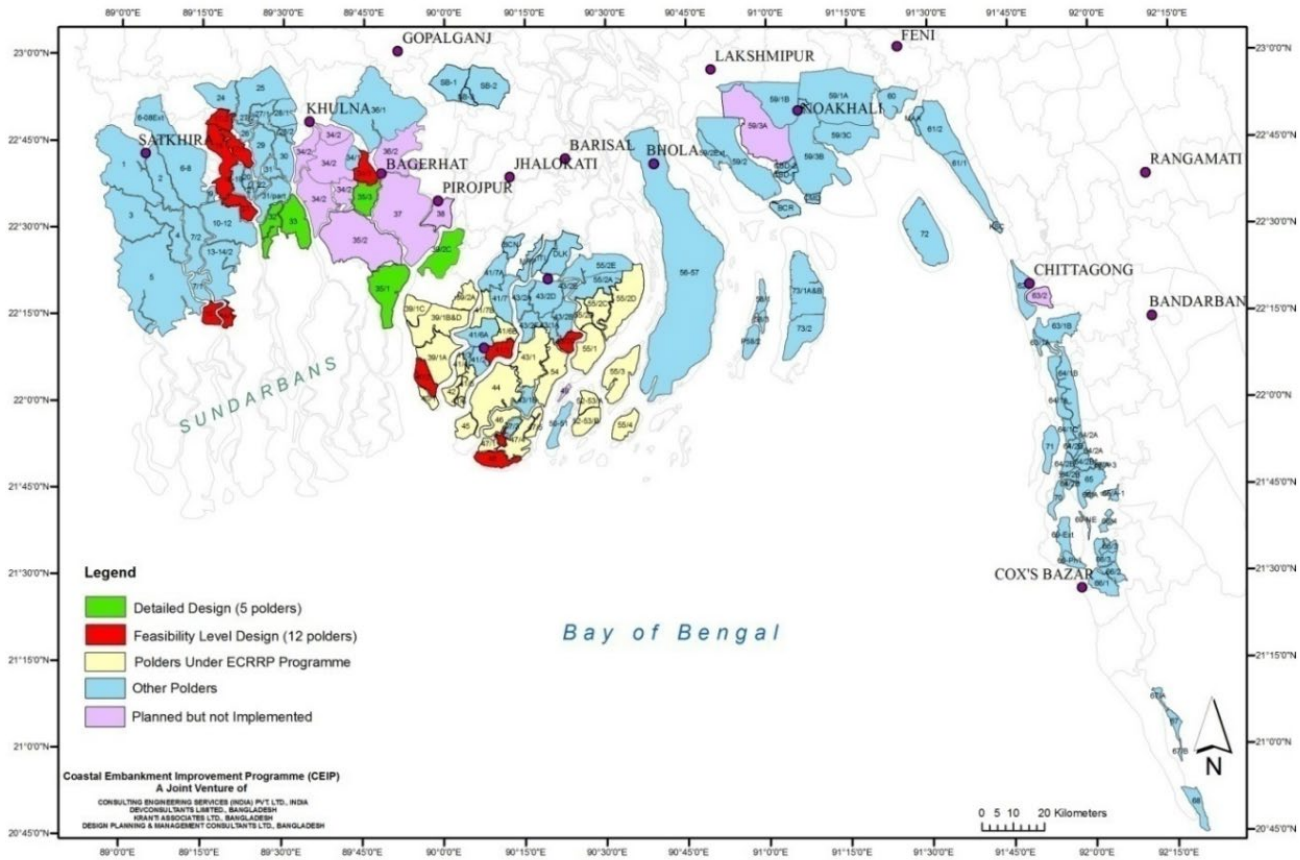
Table 1. Bangladesh Coastal Embankment Improvement Project (CEIP-1) Components

CEIP-1 Component	Total Funds (million USD)	CIF PPCR Grant Funds (million USD)
Rehabilitation and improvement of polders	$291	$20
Social and environmental management	$56	$0
Construction supervision, monitoring and evaluation, coastal zone monitoring	$32	$5
Project management, technical assistance, strategic Studies	$21	$0
Total	**$400**	**$25**

Source: World Bank, Project Appraisal Document for Coastal Embankment Improvement Project Phase 1.

The work is being carried out in phases that are referred to as packages. As of March 2022, the rehabilitation of the polders in Package 1 was nearly complete, and Package 2 was more than half-way through. The value of the contract for Package 1 is $100 million,[12] and the contract for Package 2 is estimated to be $186 million.[13,14] For analytical purposes, we treat the Package 1 polder rehabilitation as completed in 2021, and the Package 2 rehabilitation as completed in 2023. Figure 1 shows a map of the project area; this is the most detailed map available, although the status of work is outdated.

Figure 1. Map of Project Area[15]



A breakdown of polders in each package is shown in Table 2 below.

Table 2. Polders by CEIP-I Package

Package Number	Polder Number	Total Polder Area (Ha)	Residential Population of Polder (2011 data; 1.4% annual growth rate)
Package 1	Polder 32	8,097	59,258
	Polder 33	8,600	86,503
	Polder 35/1	13,058	142,714
	Polder 35/3	6,790	41,828
	Subtotal Package 1	**36,545**	**330,303**
Package 2	Polder 39/2C	10,748	136,404
	Polder 40/2	4,453	84,931
	Polder 41/1	4,048	80,330
	Polder 42/3C	2,753	27,501
	Polder 47/2	2,065	7,277
	Polder 48	5,400	57,457
	Subtotal Package 2	**29,467**	**393,899**
	Total Package 1 & 2	**66,012**	**724,202**

PPCR is also funding two other projects in Bangladesh that are not examined in this case study, but are worth mentioning for context:

- The **Coastal Climate Resilient Infrastructure Project** aims to enhance the climate resilience of coastal infrastructure in 12 rural coastal districts in Bangladesh. The project also aims to reduce poverty and raise incomes by improving access to social services and education and economic opportunities. This will be done by building and improving existing roads, bridges, culverts, cyclone shelters, and markets in a sustainable and climate-resilient way.
- The **Coastal Towns Environmental Infrastructure Project** aims to strengthen climate resilience and disaster preparedness in eight vulnerable coastal *pourashavas* (secondary towns) by providing climate-resilient municipal infrastructure and strengthening institutional capacity, local governance, and public awareness to improve urban planning. Infrastructure improvements will focus on drainage, water supply, sanitation, cyclone shelters, and other municipal infrastructure, such as emergency access roads and bridges, solid waste management, bus terminals, slum improvements, boat landings, and markets.

Development Impact Pathways and Case Study Focus

The objectives of CEIP-1, as stated in project documents, are to increase the area protected in selected polders from tidal flooding and frequent storm surges, improve agricultural production by reducing saline water intrusion, and improve government capacity to respond to crises or emergencies.[16] This case study focuses mainly on DIs associated with polder rehabilitation, including farmland protection and revitalization, increased crop yields and revenues, resulting in enhanced household wealth, improved livelihood and quality of life benefits, and regional economic benefits. Figure 2 illustrates the impact pathways.

- The **dark blue boxes** indicate the DIs quantitatively assessed in the case study: reduced damage from extreme weather and storms; reduced tidal saltwater intrusion; improvements in cropping intensity and diversification to more profitable crops; increased farmer income; and regional economic benefits including direct, indirect, and induced job creation, and economic value-added including wages, profits, and taxes. We were able to quantify these DIs by combining a crop revenue model with regional economic modeling.
- The **light blue boxes** indicate DIs qualitatively assessed in this case study, including improved water management and access to irrigation water; community capacity building; government capacity building; better access to markets; and general mobility improvement. We explored these DIs through a review of focus group information and documents, and through interviews. Some of these DIs are inherently qualitative (e.g., capacity building); information was not available to quantify others.
- The **gray boxes** identify potential DIs not assessed due to lack of information; these include food security and health benefits. However, we discuss food security briefly later in the case study.

Figure 2. Impact Pathways for Coastal Embankment and Polder Rehabilitation

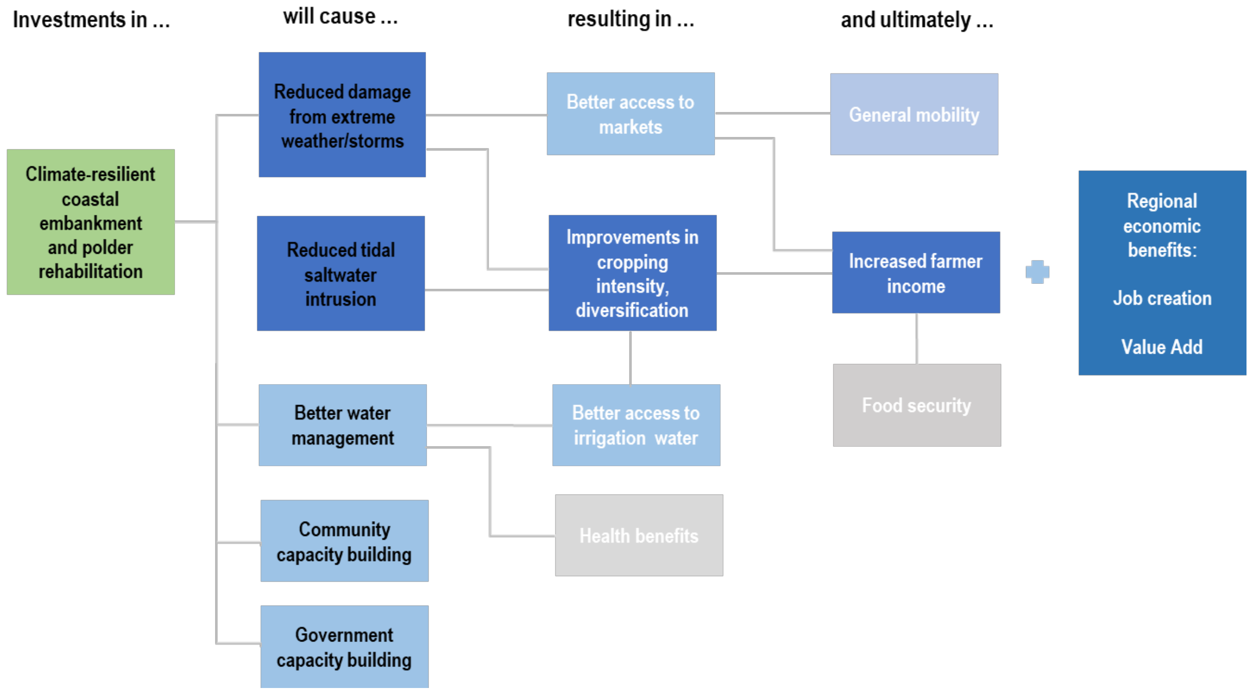


Table 3 shows the extent to which these DIs are noted in project documents as potential outcomes and/or whether they are actively tracked and measured. DIs that are tracked by the project but are not addressed in this case study (shown as gray boxes in Figure 2) cannot be assessed yet.

Table 3. Coastal Embankment and Polder Rehabilitation DIs

DI	In Project Documents?	Tracked by Project?
Reduced damage from extreme weather/storms	Yes	Yes
Reduced tidal saltwater intrusion	Yes	Yes
Better water management	Yes	Yes
Community capacity building	Yes	Yes
Government capacity building	Yes	Yes
Better access to markets	No	Yes
Improvements in cropping intensity, diversification	Yes	Yes
Better access to irrigation water	Yes	Yes
Health benefits	No	No
General mobility	Yes	Yes
Increased farmer income	Yes	Yes
Food security	Yes	Yes
Regional economic benefits: Long-term direct, indirect induced job creation	No	No
Regional economic benefits: Value added	No	No

This case study was originally also meant to study the benefits of afforestation activities that are part of CEIP-I. These are shown in the impact pathway model in Figure 3. However, we learned that it is premature to assess most DIs from afforestation programs, including crop protection and increased income from commercial forestry, because the programs were only just getting underway in most polders when this study was conducted. Most of the boxes in the impact pathway model in Figure 3 are therefore gray, indicating that it is too soon to evaluate those DIs.

Figure 3. Impact Pathways for Coastal Embankment and Afforestation

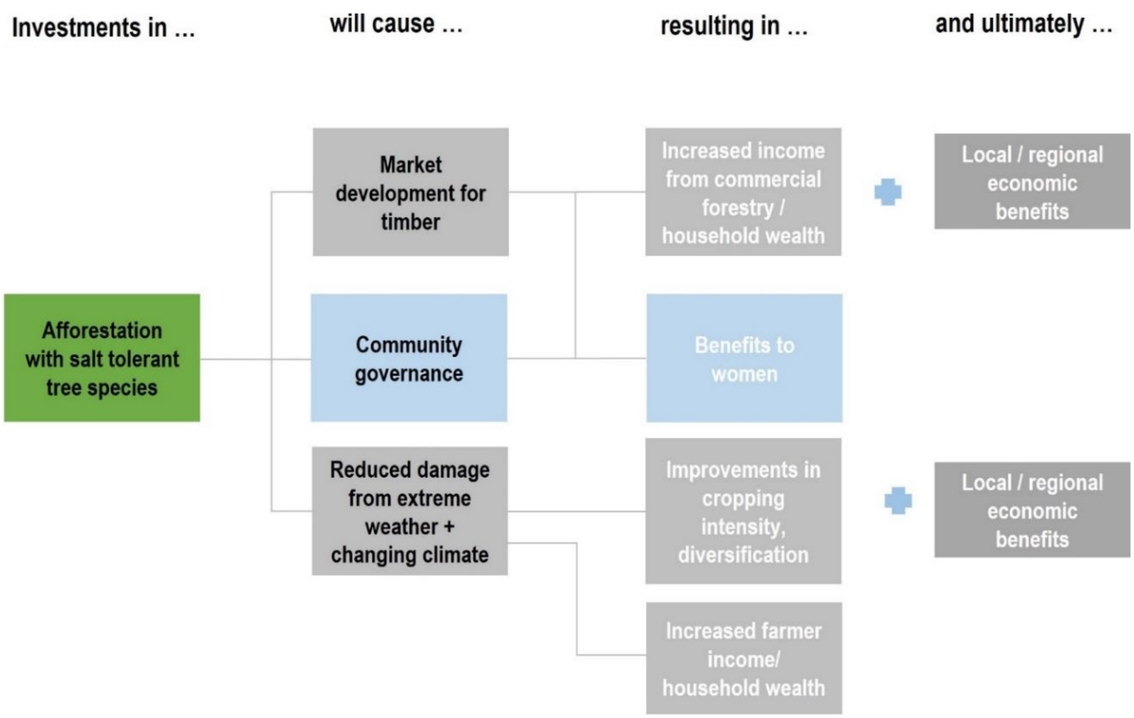


Table 4 examines the extent to which DIs associated with afforestation activities are included in project documents and in project tracking.

Table 4. Coastal Embankment and Afforestation DIs

DI	In Project Documents?	Tracked by Project?
Market development for timber	Yes	No
Community governance	Yes	No
Reduced damage from extreme weather + changing climate	Yes	Yes
Increased income from commercial forestry/household wealth	Yes	No
Benefits to women	Yes	No
Improvements in cropping intensity, diversification	Yes	Yes
Increased farmer income/household wealth from forestry	Yes	No
Local/regional economic benefits	Limited	No

Table 5 below describes the roles of a few key stakeholders.

Table 5. Key Project Stakeholders

Stakeholders	Roles
Ministry of Water Resources	Government oversight for water resource planning, and for construction of embankment projects
Bangladesh Water Development Board (BWDB)	Government implementing agency
Bangladesh Forestry Department	Collaborating agency for afforestation
Local/district governments	Interface with national government agencies
Water management organizations/associations (WMOs/WMAs)	Community-based coordination of water resource use
Project Steering Committee (Secretaries of Water Resources, Finance, Agriculture, Environment, Public Health Engineering, Forestry, Wildlife; NGO representative; local/district administration)	Forum for guidance, policy advice, project coordination, and addressing inter-agency issues

The data used for the DI analysis were collected primarily from the documents reviewed, including records for focus groups conducted by the firm hired by BWDB to conduct monitoring and evaluation (M&E). The evaluator is responsible for monitoring project impacts and implementing the Environmental Management Plan (EMP) and the Resettlement Action Plan (RAP). The M&E firm evaluates the project's success in terms of meeting stated objectives, and assesses its physical, hydrological, environmental, social, and economic impacts. The M&E activities provide continuous feedback to the government and its development partners on the project's performance.

Key documents reviewed include the World Bank's 2013 Project Appraisal Document and the CEIP-I Baseline Survey Report, which provides demographic baseline data for 2016 and 2018 for key DIs such as cropping intensity and yields, agricultural revenues, health and nutrition, and status of women. The key source of post-implementation data is the January 2022 Focus Group Presentation and underlying data for 11 focus groups conducted by the M&E evaluator with affected farmers in late 2021. IEc used data from these sources to conduct crop revenue modeling and input/output economic modeling. IEc also conducted seven remote interviews with key stakeholders, including two World Bank officials, two government officials, the M&E evaluator, a local NGO that has been involved in the project, and a representative from a farmers' organization. Sub-Appendix 1B provides further details about the data sources used in this case study.

Development Impacts from Polder Rehabilitation

Farmer livelihoods

The CEIP-I project is massive in scale and affects mostly agricultural lands; total cultivated area across both packages is about 53,000 hectares. The rehabilitation of the polders provides a variety of benefits to farmers and agricultural lands, including storm surge protection, prevention of tidal flooding, an ability to increase cropping intensity, and the ability to plant more profitable crops. Interviewees and focus group participants all agreed that the completely rehabilitated polders generally work as intended to reduce both chronic, daily saltwater intrusion and inundation during storms and cyclones. The crop revenue modeling conducted for this case study is focused on estimating and monetizing increases in crop production made possible by these benefits.

Cropping intensity

Bangladesh has two main cropping seasons: Rabi, from mid-October/November to March, when temperatures are coolest, and Kharif, the hotter season, the second half of which includes the monsoon season in July–September.[17] Because the majority of the Rabi season is drier than the others, rainfall and river flows that dissolve and transport salt from the soils diminish. As a result, saltwater intrusion is particularly damaging to crop yields in the Rabi season.

As reported in the focus groups and by interviewees, cropping intensity has increased during the Rabi season in the areas where polder rehabilitation has taken place. Table 6 shows the estimated cropping intensity before the rehabilitation of the polders in 2018 and 2021, the cultivable areas for each polder, the crops grown, and the high and low estimates of revenues per hectare. As shown in the table, Rabi cropping intensity increased from 2018 to 2021 for five of the 10 polders included in Packages 1 and 2. Most of the intensity improvement to date is from Package 1, which makes sense, because work has been completed throughout those polders. Specifically, Rabi cropping intensity is increasing by about 12 percent per year.[18]

Revenues were estimated using the range of yields collected in the focus groups and crop prices provided in the Project Appraisal Document from 2013. Revenues vary across polders, ranging from $295/ha to $1,180/ha. In contrast to the Kharif seasons, cropping intensity in the Rabi season changed over the years 2018 to 2021, particularly for polders in Package 1, where farmers have already benefited from the rehabilitation over this period. Table 6 presents crops planted during the Rabi season; some revenues may be realized in Kharif I, including revenues from watermelon production.

Table 6. Harvested Areas, Crops Grown, and Revenues in the Rabi Season by Polder

Polder No.	Rabi Cropping Intensity		Total Cultivable Area (ha)	Crops Grown	Revenues* (USD/ ha/Season)	
	2018	2021			Low	High
Package 01						
32	0%	33%	6,500	Watermelon	649	1003
33	40%	74%	7,600	Watermelon	295	1180
35/1	35%	60%	10,700	Pulse (khesari)	359	719
35/3	5%	18%	5,090	Boro rice, Boro/paddy hybrid	771	1096
Package 02						
39/2C	33%	33%	8,500	Pumpkin, pulses (cowpea, mung, BARI-6, khesari), Boro, Boro/paddy hybrid, lal shak	639	865
40/2	75%	75%	3,300	Pulses (mung)	321	564
41/1	78%	85%	3,440	Pulses (mung, BARI-6)	545	719
43/2C	100%	100%	2,000	Watermelon, pulses (mung, BARI-6), Boro	629	955
47/2	50%	**40%	1,850	Pulses (mung, BARI-6)	503	731
48	80%	80%	3,715	Pulses (mung, BARI-6)	519	691

*Low and high revenue estimates were calculated using the low and high yields from the "typical yield range" provided by the focus group participants. These were not associated with a specific year.

**According to focus group participants, cropping intensity declined from 2018 to 2021 for Polder No. 47/2 because of the ongoing polder rehabilitation construction activity near the sluice gates. A sluice gate is a sliding wood or metal barrier used to control water flows through the polder.

Planting more profitable crops

In the Rabi season, a variety of crops are grown across polders in Packages 1 and 2. These crops include various fruits (watermelon and pumpkin), pulses (cowpea, mung, BARI-6, khesari), rice (Boro and a Boro/paddy hybrid), and vegetables (lal shak, or red spinach). In the Rabi season in particular, high salinity previously reduced productivity and limited the types of crops that could be cultivated. According to focus group participants, the ability to grow watermelon, a highly profitable crop relative to others commonly grown, was a direct result of soil recovery and reduced salinity following polder rehabilitation. Watermelon was not widely grown in the area previously. Moreover, farmers who participated in the focus groups noted good coordination and information sharing with farmers in neighboring polders who led the way for planting watermelon during the Rabi season. In addition, increased freshwater access due to polder rehabilitation, discussed below, is another factor that can support farmers in diversifying plantings; one interview noted that sunflowers, watermelons, and other vegetables can now be planted in some areas where they could not previously be planted.

Increased farmer income

The impacts to farmer revenues are estimated differently across the packages.

- For Package 1, where the most data are available, we use estimated storm surge recurrence intervals with and without polder rehabilitation and estimated areas regularly inundated by tidal flooding for each of the four polders. For increased harvested area in the Rabi season, we use increases in cropping intensity collected during focus groups in late 2021. Benefits for the Rabi season represent actual benefits from 2018 to 2021 compared with 2018, and these are projected by extrapolation after 2021.
- For Package 2, we rely on the Package 1 average storm surge recurrence interval with and without polder rehabilitation, the share of cropland regularly inundated by tidal floods, and estimated increases in cropping intensity in the Rabi season. Benefits for this package are projected to start after the completion year in 2023.

Table 7 below shows a forecast of annual benefits of the storm surge protection, protection from tidal flooding, and increased harvested area in the Rabi season for the high and low estimates, expressed as increases in annual farmer revenues for 2025 and 2035. Farmer revenues are largest for Package 1, where the completion date is earlier and the Rabi season harvested areas in the baseline year are lower than in Package 2, allowing for more growth in the cropping intensity.

Table 7. Increases in Annual Farmer Revenues as a Result of Polder Rehabilitation

	Annual Farmer Revenue Benefits of Polder Rehabilitation (Millions of USD/Year)							
	Storm Surge Protection		Tidal Flooding Reduction		Cropping Intensity Increase Rabi Season		Total	
	Low	High	Low	High	Low	High	Low	High
Package 1								
2025 (4 years after completion)	0.6	0.9	6.6	15.4	5.7	15.5	**$12.9**	**$31.7**
2035 (14 years after completion)	0.6	0.9	13.6	29.3	6.8	17.2	**$21.1**	**$47.4**
Package 2								
2025 (2 years after completion)	0.6	0.9	0.0	0.0	2.3	3.3	**$3.0**	**$4.2**
2035 (12 years after completion)	0.6	0.9	13.6	19.2	3.8	5.3	**$18.0**	**$25.3**
Total								
2025	1.2	1.7	6.6	15.4	8.0	18.8	**$15.9**	**$35.9**
2035	1.2	1.7	10.6	22.5	27.2	48.5	**$39.1**	**$72.7**

Figure 4 illustrates annual benefits for the two packages from 2018 to 2040. Benefits increase over time as the polder rehabilitation is completed and begins to bring additional revenues for farmers. Crop revenue modeling shows that by 2032, the total annual benefits to farmer revenues from polder rehabilitations are $39–73 million per year, for an average of $56 million per year. This equates to about $90 /ha of benefits.

Table 8 presents benefits per hectare of cultivable area for select years between 2021 and 2035.

Figure 4. Total Annual Benefits across the Two Packages for the High and Low Estimates from the 2018 Baseline to 2040

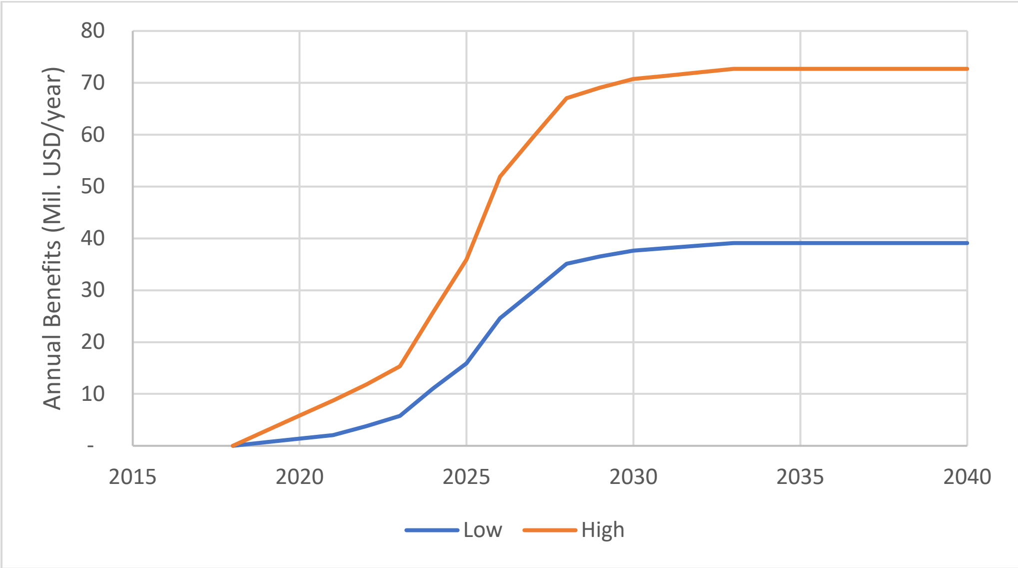


Table 8. Total Annual Benefits per Hectare across Packages

Year	Annual Benefits of Polder Rehabilitation Per Area (USD/ha/Year)	
	Low	High
2021	3.3	14.1
2025	25.5	57.7
2030	60.6	113.7
2035	62.9	116.9

Other benefits for farmers

Access to markets

The embankments rehabilitated as part of CEIP are also roads; local community members call them rastas. Prior to polder rehabilitation, in more remote areas, such as polders nearest to the Sundarban area, Shoronkhola, and Dakob, travel and farmer access to markets was difficult. Now, according to multiple interviewees, as polders have been rehabilitated, business connections and communication networks have redeveloped, and people use the embankments to carry their vegetables and crops to central markets for sale. This has helped boost the local economic impacts of the project, which are discussed more below. However, focus group participants noted that challenges remain once crops get to market, as there is a shortage of market spaces to sell crops.

Water access

One interviewee noted that due to improved drainage and flushing structures that prevent saltwater from entering farming areas, farmers now take rainwater from the re-excavated drainage channels and use it for irrigation. In the Package 1 and 2 polders, about 15 percent of households irrigate their lands, using both surface water and groundwater.[19] Thus, polder rehabilitation has provided a potentially more convenient and less expensive source of irrigation water, contributing to improved livelihoods. Another interviewee said increased freshwater access can also support farmers in diversifying crops.

Better management of water

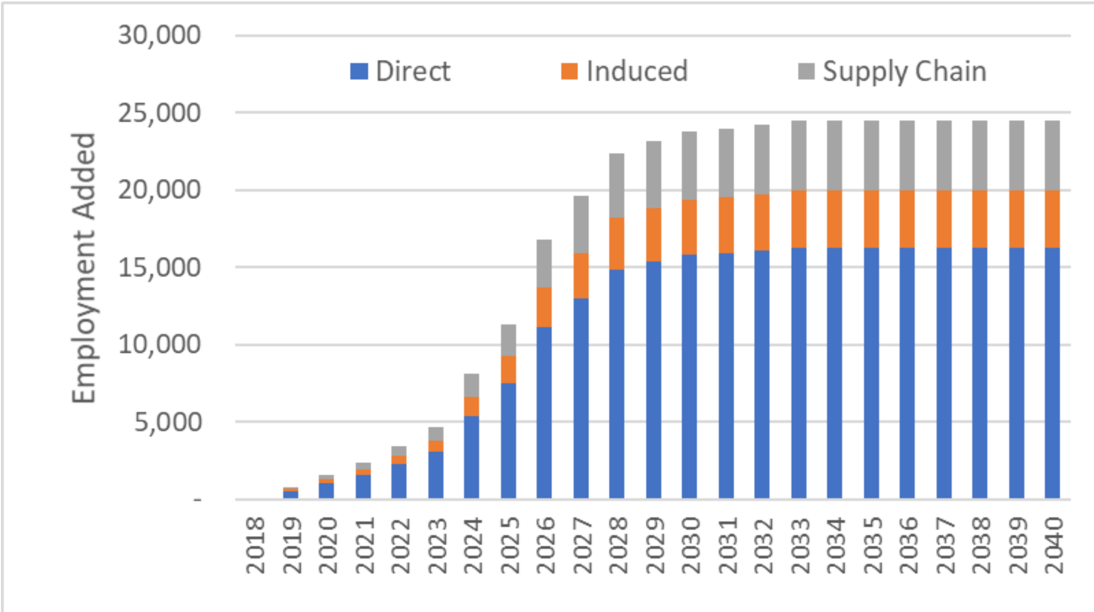
Some farmers who participated in focus groups also noted that water management organizations (WMOs) are providing improved water management that meets farmers' needs better than the way water was managed pre-rehabilitation, although other farmers disagreed. Some farmers noted that shrimping operations had been closed, which reduced demand for high-salinity water and allowed for land to recover. WMOs are discussed more below.

Economic impacts

Job creation

We used the JIM model to estimate the average annual revenues presented above from the 2018 to 2040 period.[20] Note that given the national-level statistics employed in the tool, the JIM results are considered robust at the portfolio level, so the results for the individual investments we analyze here are indicative. Figure 5 presents the direct, induced, and supply chain jobs supported from increased agricultural revenues. By 2032, nearly 25,000 jobs are supported annually–roughly 66 percent directly, 15 percent induced through spending of wages, and 19 percent from upstream supply chain effects. About 45 percent of the direct jobs, 33 percent of induced jobs, and 36 percent of supply chain jobs are estimated to go to women. Most of the induced and supply chain jobs are informal, at about 80 and 89 percent, respectively.

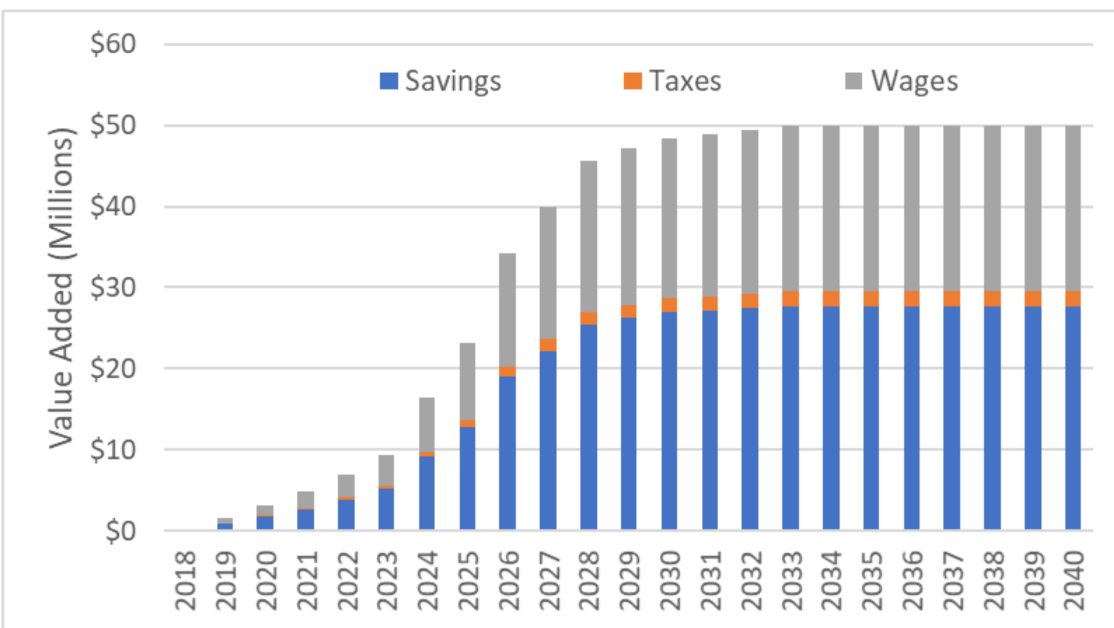
Figure 5. Direct, Induced, and Supply Chain Jobs Supported Due to the Increases in Agricultural Revenues



Economic value added

By 2032, the $56 million increase in annual agricultural revenues will generate a total of $50 million in *annual* value added; see Figure 6 below. This is made up of increased wages (41 percent), savings (56 percent); and taxes (4 percent). Although not presented in the figure, wage increases are split roughly evenly between direct and supply chain effects, but closer to two-thirds of the savings are held as direct effects.

Figure 6. Economic Value Added Benefits of Increased Agricultural Revenues



Social impacts

General mobility

As noted above, the polders are also roads. Prior to the rehabilitation of the polders, many areas lacked ready access to a reliable road. One interviewee noted: "The ability to move and communicate is life-changing for community members that were living in areas where the polders had failed, and now they are functional again." The road provides the way to go to the market, to go to school and work, to access healthcare, and to travel to other areas of the region and country. For example, one interviewee noted that people near Shyamnagar have started using the embankment as a road, and this connects them to other areas. An indirect benefit is that the polders are less likely to be damaged—for instance, from holes made by shrimpers—since people value their use for transportation.

Food security

It is common for food costs to make up a large share of poor households' expenses. Food is the largest household expense for families in the CEIP-I area; households surveyed in 2015 and 2017 for the baseline/midline report indicate that annual food expenditures comprise 50–60 percent of all expenses.[21] Post-polder rehabilitation household survey data are not available, but a government official provided very thoughtful comments on food security, quoted verbatim below:

> "When marginalized people or rural people get the opportunity to increase their income, it will definitely enhance their food security and nutrition. [But] it is too early to comment on food security. All I can say is food security is a vast area and there are so many components. We found data about the improved yield of the food production and varieties of crops. But food security involves other issues, like purchasing power and nutrition. We can only say that the production and crop diversification of the agricultural products has increased in the project areas."

Capacity building

Community capacity

The project is designed to establish and empower local water management associations and organizations (WMOs/WMAs), led by community members, to make decisions about drainage, and letting water in and out of sluice gates. WMA members conduct minor upkeep and periodic maintenance of the polders. The groups are also active during weather emergencies; when an incoming cyclone is known, they help to alert local community members.

WMOs are a federated system—representatives from each polder sit on WMOs. WMOs also include landholders, BWDB, and representatives from the Department of Agricultural Extension. WMOs have existed for about 20 years, but multiple interviewees and focus group participants said they had not functioned well prior to the CEIP-I project, which provided resources to better organize them. The government hired five NGOs to mobilize them, providing training and registering new WMOs.

According to two government and World Bank interviewees, WMOs are performing well in their duties. However, focus group participants largely disagreed with this sentiment. In general, focus group participants said that WMA/WMOs do not have a good understanding of their responsibilities, and that communication gaps persist. Also, some focus group participants indicated that WMAs have no working relationship with BWDB. It should be noted that subsequent to the focus groups, BWDB and WMAs signed a memorandum of understanding (MoU) clarifying responsibilities.

Government capacity

Prior to the project, only limited and fragmented data about the region's morphology were available. The comprehensive data collection and analytics developed by the project are greatly expanding the knowledge base of the area's natural systems, improving the government's capacity to develop a more informed long-term vision for the area, and informing better land use and water resource planning. The project is employing teams of global and local experts, including Danish Hydraulics, Columbia University, and experts from local universities. Knowledge developed by the team is shared on a regular basis with government agencies, facilitating capacity building at BWDB and the Institute of Water Development. As a result of the project, 1,031 person-days of training have been provided to BWDB officials (the result framework target is 1,200). Furthermore, three BWDB officials completed master of science (M.Sc.) degrees from IHE Delft Institute for Water Education, Netherlands as part of capacity building of BWDB.

Development Impacts from Afforestation

CEIP-1 includes an afforestation component to protect the coast from storm surges and protect the livelihoods of local farmers from damage caused by storms. Already, 610 ha have been afforested, exceeding the target of 600 ha. Afforestation efforts are generally focused on planting salt-tolerant mangroves and golpata (a type of tall tree), to protect indigenous networks of trees with stronger roots that are suited to this region. Plantings also include other fast-growing timber species that can be harvested for profit, as well as fruit trees. They are also focused on setting up programs for local community members to manage afforestation projects.

As discussed above, the DI pathways envisioned from afforestation include soil rehabilitation and crop protection that supplements the protection afforded by the polders, leading to additional crop intensity and diversification, and increased income and economic benefits. In addition, afforestation is designed to ultimately provide an increased income source from commercial forestry, also leading to economic benefits for local community members.

Interviewees and focus group participants explained that it is premature to try to assess most DIs from afforestation programs, including crop protection and increased income from commercial forestry, because the programs are generally only just getting underway in most polders. However, early indicators are that afforestation programs are enjoying initial success, implementing a community governance model and producing benefits for women in particular.

Community Governance

The community governance model of the afforestation programs is being implemented. According to interviewees, NGOs funded by implementing agencies have been actively setting up afforestation programs. They have trained local community members and are engaging them in day-to-day management of afforested areas within a social or community-based forestry framework to build local ownership and empower people. Local community members are engaged in both managing programs, and in assigning individuals to specific maintenance tasks. Interviewees indicated that there is a shared understanding of roles between the project implementing authority and the local community members who form the groups and maintain them, and some agreements between community groups and implementing agencies have been codified in MOUs.

Benefits Specific to Women

CEIP-I deployed five NGOs to mobilize and involve project beneficiaries in the WMOs or, more specifically, the water management group (WMG) at the sluice/village level and the WMA at the polder level. There have been 141 WMGs created so far, with 25,878 women among the general members (36 percent of the total of 72,329); 561 women have been appointed to the executive committees of the 10 registered WMAs (33 percent of the total of 1,692). This also complies with the Participatory Water Management Rules of 2014, which state that the executive committees of both tiers of WMOs must include at least 30 percent women. Under Package 1, a total of 291 women-headed households were reached, while Package 2 identified 478 such households.

The CEIP-I baseline report provides helpful context about the role of women within the local communities where coastal embankment and afforestation work is taking place. In the region, according to a household survey conducted for the project, women typically have familial decision-making power over allocation of food to families, and are often tasked with identifying supplemental income sources, such as selling eggs, as well as identifying supplemental nutritional sources.[22] According to interviewees, women are employed more often than men in community jobs created by CEIP-I afforestation projects. Most commonly, women are employed to ensure that animals, such as goats and chickens, do not walk or graze on the newly rehabilitated embankments. In addition, the fruit tree plantings can provide women with income and food source diversification for themselves and their families.

Drivers and Barriers that Affect Results

Effectiveness of rehabilitated infrastructure

DIs stemming from the coastal embankment project are predicated on rehabilitated polders working as designed to manage tidal flooding and storm surges. According to focus group participants and interviewees, in general, the polders are working as designed and soil quality has greatly improved in areas where the work has been completed. The improved soil quality has allowed an increase in cropping intensity and cropping diversification that is key to unlocking most DIs from the project. However, some technical problems are evident. For example, in some polders, main canals (khals) have had to be re-excavated for proper water management. In some places, the quality of the reconstructed polders is low, and some have already started to crack due to poor workmanship.

Limitation of cropping intensity

Economic benefits of polder rehabilitation are driven in part by an ability to increase cropping intensity. However, focus group participants noted several limitations to increasing cropping intensity outside of the Rabi season. In all polders, 100 percent of the cultivable area is harvested in the Kharif-II season, while harvested areas vary for Kharif-I across polders. The reasons provided by focus group participants for not planting in Kharif-I vary, but include not having enough time or space; that planting during this season has not been profitable in the past; the lack of places for drying because of the heavy rainfall;

and the use of land for grazing cattle. According to focus group participants, cropping intensity did not change in 2018–2021 in either Kharif season. Finally, some farmers also do not plant in the Rabi season; reasons provided include persisting salinity, water shortages, waterlogging, and high costs.

Cost overruns and need to scale back the project

The economic and social benefits of polder rehabilitation are obviously tied to the scale of the project. CEIP-I experienced significant cost overruns that led to the elimination of a third package of polders from the project. The 2020 restructuring paper noted that the scope would be reduced from 17 to 10 polders due to the financing constraints, and the remaining seven polders, which had all technical designs ready, would be moved to a potential second phase, along with additional polders.[23] The paper said the source of financing for a second phase had yet to be determined, but the reduction in scope "would allow for the ongoing 10 polders to be completed within the available funds considering the cost increases and the need to carry out additional protection works resulting from new damage and erosion during implementation." One interviewee indicated that the Bangladeshi government would fund the rehabilitation of the remaining seven polders, but that has not yet occurred, and other interviewees were uncertain about the prospects. The implication for DIs is simply that the scale of economic and social benefits is smaller than if Package 3 had been funded.

Water management organizations/associations off to a slow start

WMOs and WMAs are important for maintaining some day-to-day operations of polders. However, as noted above, we have mixed information on the performance of WMOs and WMAs to date. Focus group participants stressed that WMOs need to properly control sluice gates for water flows with respect to tidal movement, and that there is continuous leakage even when gates are closed. Moreover, focus group participants indicated that WMAs lack working relationships with BWD.

Management of conflicts with shrimping

The economic benefits of polder rehabilitation are also influenced by the ability to navigate water management conflicts between commercial shrimping and farming**.** Commercial shrimp production began to proliferate in the CEIP-I project area, and more broadly in coastal Bangladesh, in the 1970s, with support of the government at the time. Then, officials viewed shrimping as a way to improve household income and food security by creating a more reliable complementary source of income. In the CEIP-I project area, Package 1 areas had roughly equal revenues from fish/shrimp production and crop revenues in 2015, although crop revenues dominate in Package 2. During the last 50 years, some farmers converted their lands to shrimping. Although shrimping created jobs and provided additional income, it also exposed farmers to the vagaries of the global demand for shrimp, which led to many industry losses during global recessionary periods. Some farmers have also been pressured to convert their land, and shrimping operations exacerbated saltwater intrusion and soil degradation.[24] According to interviewees, shrimpers have historically had more political power and better representation than farmers.

Shrimp production led to conflicts with farming in some locations within the project area. Prior to CEIP-I, some shrimpers made holes in the lower part of the embankment to allow saltwater into the river. They also placed wooden sluice gates illegally to foster mixing in of saltwater. Though there are laws against breaking or making holes in the polders, one interviewee noted that fines are too small to be a serious deterrent. As a consequence, the foundation of the embankments became fragile, and the bindings of the soil got broken or loose, which contributed to dam failure.

In some polder areas that have been rehabilitated and are slated for agricultural use, shrimping conflicts still occur. Tension exists between those who want to grow rice and other crops, and those who want to continue to use the area for shrimping and crabbing. Shrimpers will still sometimes let the water in at a time that will affect the yields of the freshwater crops, or may still illegally put holes in the polders. It is not clear how widespread the problem is. As noted above, embankments used as roads are less likely to be broken or have holes made in them, since all parties have an interest in maintaining the transportation network. One of the focus groups noted that shrimping has been discontinued in one polder, Polder 33, post-rehabilitation; other focus groups did not comment on shrimping operations.

Limited marketplace access

The economic benefits of polder rehabilitation also depend in part on farmers' ability to access central markets. Some farmers have buyers and trade relationships that do not rely on central markets, but the markets are an important avenues for many farmers to sell their harvests. Focus group participants indicated that there is a shortage of physical space at markets to sell crops in every polder area. Some said the market stalls available to them are too small and only run by a single person at a time. This may be a temporary barrier of markets simply needing to catch up with local farmers who are enjoying higher yields and are selling more diversified crops, but currently it is a challenge.

CIF and MDB Partner Contributions to DIs

The scale and scope of the CEIP-I project is expansive; it is the largest ongoing infrastructure project in Bangladesh, and one of the largest World Bank projects in the region. The project would not be possible without the Bank's funding and without the cutting-edge design and construction facilitated by the Bank, or the expertise and project management capabilities that the Bank put in place in collaboration with the Bangladesh government. Bangladesh government officials as well as other interviewees agreed on these points. In addition, funding dedicated to developing scientific understanding of the unique hybrid engineered and natural ecosystem, and best ways for the stakeholders to manage it moving forward, would not have been available without the Bank and CIF.

The CIF contribution to the project included $20 million in grant funds for polder rehabilitation (Component 1) and $5 million towards the coastal zone monitoring and analytics (Component 3). CIF's contribution through PPCR was critical in several ways. First, PPCR funds come as grants, while the Bank funds are concessional loans. Multiple interviewees underscored that having a small amount of grant funding was very helpful in negotiating commitments from the Bangladesh government. Second, CIF's $5 million towards coastal zone monitoring and analytics was critical both for project approval and for helping to ensure the sustainability of the rehabilitated polder system. The government was reluctant to fully fund the monitoring task, and the $5 million in PPCR funds helped to bridge a key gap.

The monitoring task was also critical for assuaging concerns of the environmental and NGO community about the government doubling down on the highly engineered polder system, which some see as detrimental to the health of the overall ecosystem. The commitment to a robust monitoring and knowledge development system was critical for garnering the support of these stakeholders and subsequently building enough political support to move forward. Finally, the extensive coastal zone monitoring is critical for understanding the morphology of the area and for developing knowledge about how the ecosystem is functioning post-polder rehabilitation, to build scientific capacity at BWDB, and inform long-term water management and agricultural planning in the area.

Future Opportunities: Lessons for CIF and Other Climate Funders

Lessons to apply to future polder rehabilitation work and other PPCR projects

As discussed above, the original CEIP-I project plan covered 17 polders, but the project was scaled down to two packages with a total of 10 polders. It remains uncertain whether funding will be mobilized to rehabilitate the remaining seven or other polders. If it is, several lessons learned through Packages 1 and 2 could be applied to future work to increase development impacts. There are also lessons that are more broadly applicable to PPCR projects.

The polder rehabilitation is a highly complex engineering undertaking. Interviewees and focus group participants noted that if DIs are to be fully realized, the engineering design must be faithfully constructed, and those charged with everyday operations and maintenance must ensure that the polder systems work as intended. For example, the sluice gates need to be opened and closed on agreed-upon schedules and in response to weather conditions. This means having better institutional processes and controls in place to ensure the quality of the workmanship, to avoid some quality problems already identified by farmers, such as cracks in the polders. Better government coordination with WMOs/WMAs would help to ensure that the operation and maintenance of the polders align with the community's vision. Finally, WMO/WMA members likely require more than one-time training from NGOs hired by the government; they likely require some level of ongoing technical assistance or at least periodic training. In short, more continuous work is needed to build the capacity of these organizations and ensure effective local governance of the polder systems. The need to provide more than one-time training to launch new community governance initiatives is also broadly applicable to PPCR initiatives.

Another lesson learned relates to agricultural practices and farmer needs. Farmers noted a number of limitations to increasing cropping intensity and diversification outside of the Rabi season, including high costs and lack of feasibility of planting during certain times and in certain places. It is not clear whether those barriers are absolute or could potentially be overcome if farmers changed their current practices. Increasing cropping intensity, planting in each season, and further diversifying to more profitable crops are other keys to unlocking DIs associated with polder rehabilitation. The World Bank and/or CIF may therefore want to invest in a study to fully understand the barriers to making agricultural changes that enable farmers to realize the full benefits of polder rehabilitation. More generally, CIF should undertake barriers studies to understand the full spectrum of challenges to increasing cropping intensity or changing agricultural practices, as due diligence to inform similar interventions under PPCR.

Ensuring demand for farm produce as yields increase

To date, farmers have been able sell their additional crops, despite the limited market space. However, our modeling suggests yields will continue to increase, resulting in larger quantities of produce available for sale, especially as farmland within Package 2 polders recovers. CIF may want to use some of its monitoring budget to help forecast supply and demand curves for key crops, and work with the World Bank to promote more crop diversification, and/or provide market facilitation services, to align supply and demand. CIF may want to consider investing in market infrastructure, technologies (e.g., cold chain), and/or logistics services to help keep crops fresh longer, and potentially opening doors to more profitable value chains and markets. CIF should also closely monitor the actual demand for key crops in future years, and actual prices, to ensure that economic DIs from increased crop yields are realized.

Using forthcoming project M&E data to further assess DI outcomes

The scope of this case study includes a retrospective assessment of DIs from activities completed to date, and forecasting DIs associated with agricultural improvements, increased revenues, and economic impacts from these completed activities. However, polder rehabilitation did not begin until 2018, and due to delays around the COVID-19 pandemic, only work on Package 1 polders was completed by 2021. Therefore, as of the writing of this case study in May 2022, we have a narrow view into the DIs already realized by the project, as we have only 1–2 years of data post-soil recovery, for only a few polders.

Fortunately, the CEIP-I project has funded extensive M&E activities, including longitudinal primary research, which is tracking detailed data from local residents on farming conditions and practices, road connectivity, health and nutrition/ food security, literacy and education, income, the role of women, and status and role of local institutions.[25] The M&E contractor will repeat the survey from the baseline/midline report in the future, as a post-implementation survey, which should provide a wealth of data for assessing DIs. IEc's understanding is that the contractor will continue to use the same detailed household survey and same sampling approach for the final survey that it used in 2016 and 2018, allowing CIF to readily conduct DI trend analysis.

Sub-Appendix 2A. CEIP-I Budget Components

Component	Description	Budget
Component A	**Rehabilitation and Improvement of Polders** **Component A1: Rehabilitation and Improvement of Polders ($286 million)** will finance activities to increase community resilience to tidal flooding and storm surges, including (i) rehabilitation of critical portions of polder embankments including slope protection work, (ii) increasing embankment height in some stretches to improve resilience, (iii) repairing and upgrading drainage and flushing systems within polders, and (v) improving operations and maintenance (O&M). The majority of CIF grant funding ($20 million) is contributing to this subcomponent. **Component A2: Afforestation ($5 million)** will finance the planting of selected mangrove and other salt tolerant species on BWDB's land to demonstrate the important role of a protective belt on the tidal inundation zone on the riverside of the embankment. Afforestation improves the security of embankments and community livelihood, as it provides protection from tidal flooding and storm surge.	**$291 million** CIF PPCR grant (Component A1): $20 million
Component B	**Implementation of Social and Environmental Management Frameworks and Plans** **Component B1: Implementation of Social Action Plans ($3 million)** will support polder stakeholders and beneficiaries by establishing polder committees that determine the competing needs and uses for water resources and decide on the operation of hydraulic infrastructure. In addition, the component will fund the establishment of participatory Water Management Organizations (WMOs) that will be responsible for the operation and minor maintenance works of the polders. **Component B2: Implementation of Social Management and Resettlement Policy Framework (SMRPF) and Resettlement Action Plans (RAPs) ($49 million)** will finance the implementation of the RAP, embankment monitoring, public consultation plans, land acquisition, and the resettlement and rehabilitation of persons adversely affected by the project. **Component B3: Implementation of Environmental Management Framework (EMF) and Environmental Management Plans (EMPs) ($4 million)** will finance (i) the preparation of environmental impact assessments for the polders for which one has not been completed; (ii) the implementation of the EMP and environmental mitigation and enhancement measures; and (iii) the establishment of an environmental monitoring system in BWDB to enable it to track continuous improvement in environmental performance of the polder system.	**$56 million**
Component C	**Construction Supervision, Project Monitoring and Evaluation, and Coastal Zone Monitoring** **Component C1: Detailed Design and Construction Supervision ($16 million)** will finance consulting services for (i) surveys and designs of remaining polders outside of the five for which detailed designs were complete at the beginning of the project and (ii) construction supervision of rehabilitation and improvement of coastal embankments. **Component C2: Third Party Monitoring and Evaluation of Project ($4 million)** will finance consulting services for continuously monitoring project activities and providing feedback to the government and the implementing agency on the project's performance through third-party assessment and monitoring of key aspects of project implementation. **Component C3: Long Term Monitoring, Research and Analysis of Bangladesh Coastal Zone ($12 million)** will support a comprehensive monitoring and morphological assessment of the Bangladesh Delta in order to enhance the limited understanding of the region's complex natural phenomena. This program will extend the current monitoring systems in coastal Bangladesh to generate data, information,	**$32 million** CIF PPCR grant (Component C3): $5 million

Component	Description	Budget
	and new knowledge for assessments of effects of multiple drivers on the environment of coastal zone and guide future design, rehabilitation, and improvement requirements.	
Component D	**Project Management, Technical Assistance, Training and Strategic Studies** **Component D1: Project management support and audits** will support BWDB to establish and maintain a Project Management Unit (PMU) and finance all necessary audit reports. **Component D2: Technical assistance and training** will provide BWDB with institutional capacity building and technical assistance and training, and will support the coordination and management of the PPCR at a program level. **Component D3: Strategic studies and future project preparation** will provide resources for necessary strategic studies (including the continuous updating of the strategic polder assessment and necessary preparatory studies for future phases of the CEIP).	**$21 million**
Component E	**Component E: Contingent Emergency Response ($0 allocation)** allows the Government of Bangladesh to request that the World Bank reallocate project funds to support response and reconstruction in case of a major disaster.	**$0** (provisional)
Total		**$400 million**

Sub-Appendix 2B. Data Sources

Data used for the DI analysis is collected primarily from document review, including review of recent focus groups conducted by BWDB's monitoring and evaluation (M&E) firm. These data sources provided input that IEc used to conduct crop revenue modeling and input/output economic modeling.

Document review

Data were available from World Bank documents explaining the nature and objectives of the CEIP-I project. Key documents reviewed include the Bank's 2013 Project Appraisal Report and the CEIP-I Baseline Survey Report, which provides demographic baseline data for 2016 and 2018 for key DIs such as cropping intensity and yields, agricultural revenues, health and nutrition, and status of women.[26] The key source of post-implementation data is the January 2022 Focus Group Presentation and underlying data for 11 focus groups conducted in late 2021 with affected farmers by the M&E evaluator. Researchers collected data during these focus groups on post-polder rehabilitation changes to farming practices, as well as longitudinal data on embankment conductions; drainage conditions; sluice gate conditions; and salinity conditions. The focus groups explored remaining barriers to increasing cropping intensity, planting more profitable crops, and implementation of the WMAs to date.

We also reviewed World Bank implementation status reports. Other data sources include contextual documents, journal articles, reports, and news articles.

Interviews

The IEc team conducted a total of seven interviews with key stakeholders, including two World Bank officials, two government officials, the government's M&E contractor, a local NGO that has been involved in the project, and a representative from a farmers' organization. Interviewees are listed in the table below. Bank officials provided extensive information about the project, as did the M&E evaluator. Government officials provided information consistent with that provided by the Bank. Although we worked with an in-country research firm to reach out to interviewees, the necessity of remote interviews hindered our ability to reach populations of interest. We reached out to several farmers' organizations, but only one agreed to an interview. We also reached out to several NGOs, but the only one that agreed to an interview did not have recent knowledge of the project. We stopped pursuing interviews after we received the focus group data, which were a very rich source of information and feedback from farmers.

Organization	Designation	Name
World Bank	Task Team Leader	Swarna Kazi
World Bank	MDB Focal Point	Zhihong Zhang
World Bank	Additional Secretary, Government Focal Point	Abdul Baki
Government of Bangladesh, Ministry of Water	Project Director	Syed Hassan Imam
Sheladia Associates Inc.	M&E Lead	Jan Twarowski
Kendrio Krishok Moitree (KKM) (federation of farmers' groups)	Central Committee Member	Ala Uddin
Coastal Livelihood and Environmental Action Network (CLEAN)	Chief Facilitator	Hasan Mehedi

Sub-Appendix 2C. Methodology for Crop Revenue Modeling

Our understanding is that polder rehabilitation is nearly complete for Package 1, and roughly more than halfway complete for Package 2. For the sake of the crop revenue analysis, we assume the rehabilitation for all Package 1 polders was completed in 2021 and that Package 2 polders will be complete in 2023. We also use 2018 as the baseline year since 2018 is the earliest year cropping intensities were collected in the farmer focus group discussions and none of the polder projects were complete until 2021.[27] As of November 2018, physical progress on the four polders in Package 1 was 50 percent and construction work had not begun on the six polders in Package 2.[28]

Crops and revenues

As noted, Bangladesh's cropping calendar is typically split into three growing seasons: Kharif-I, Kharif-II, and Rabi. Table 9 shows the cropping intensity for both Kharif-I and Kharif-II, cultivable area, crops grown, and a range of calculated seasonal revenues for the period 2018–2021. In the Kharif-II seasons Aman rice is grown including a high yield and local variety of Aman, and in Kharif-I Aus rice is grown, but only in the Package 2 polders. Revenues were calculated using the range of yields collected in the focus group discussions conducted in November of 2021, which focus on 2018 to 2021, and crop prices reported for Polder 35/1 in the Project Appraisal Document. In all polders, 100 percent of the cultivable area is harvested in the Kharif-II season, while harvested areas vary for Kharif-I across polders. The reasons provided by focus group participants for not planting in Kharif-I vary, but include not having enough time between Rabi and Kharif-II; planting during this season has not been profitable in the past; lack of places for drying because of the heavy rainfall; and use of land for grazing cattle. According to focus group participants, cropping intensity did not vary for the years 2018 to 2021.

Table 9. Cropping Intensity, Cultivable Area, Crops Grown, and Estimated Revenues in the Kharif Seasons by Polder, Constant over 2018–2021

Polder No.	Package	Cropping Intensity		Cultivable Area (ha)	Crops Grown	Revenues* (USD/ha/Season)	
		Kharif-I	Kharif-II			Low	High
32	1	0%	100%	6,500	Rice (Aman)	555	807
33	1	0%	100%	7,600	Rice (Aman)	476	778
35/1	1	0%	100%	10,700	Rice (Aman)	472	738
35/3	1	0%	100%	5,090	Rice (Aman)	550	712
39/2C	2	25%	100%	8,500	Rice (Aman and Aus)	459	611
40/2	2	8%	100%	3,300	Rice (Aman and Aus)	478	657
41/1	2	95%	100%	3,440	Rice (Aman and Aus)	588	802
43/2C	2	20%	100%	2,000	Rice (Aman and Aus)	372	579
47/2	2	30%	100%	1,850	Rice (Aman and Aus)	431	637
48	2	28%	100%	3,715	Rice (Aman and Aus)	454	711

*Low and high revenue estimates were calculated using the low and high yields from the "typical yield range" provided by the focus group participants.

In the Rabi season, a variety of crops are grown across polders in Packages 1 and 2. These crops include various fruits (watermelon and pumpkin), pulses (cowpea, mung, BARI-6, khesari), rice (Boro and a Boro/paddy hybrid), and vegetables (lal shak). Table 10 shows the estimated cropping intensity before the rehabilitation of the polders in 2018 and 2021, the cultivable areas for each polder, the crops grown, and the high and low estimates of revenues per hectare. Revenues were estimated using the range of yields collected in the Focus Groups and crop prices provided in the Project Appraisal Document from 2013. Revenues vary across polders, ranging from $295/ha to $1,180/ha. In contrast to the Kharif seasons, cropping intensity in the Rabi season changed over the years 2018 to 2021, particularly for polders in Package 1 where farmers have already benefited from the rehabilitation over this period.

Table 10. Harvested Areas, Crops Grown, and Revenues in the Rabi Season by Polder

Polder No.	Rabi Cropping Intensity		Total Cultivable Area (ha)	Crops Grown	Revenues* (USD/ha/Season)	
	2018	2021			Low	High
32	0%	33%	6,500	Watermelon	649	1003
33	40%	74%	7,600	Watermelon	295	1180
35/1	35%	60%	10,700	Pulse (khesari)	359	719
35/3	5%	18%	5,090	Boro, Boro/Paddy Hybrid	771	1096
39/2C	33%	33%	8,500	Pumpkin, pulses (cowpea, mung, BARI-6, khesari), Boro, Boro/Paddy Hybrid, Lal shak	639	865
40/2	75%	75%	3,300	Pulse (mung)	321	564
41/1	78%	85%	3,440	Pulse (mung, BARI-6)	545	719
43/2C	100%	100%	2,000	Watermelon, Pulse (mung, BARI-6), Boro	629	955
47/2	50%	**40%	1,850	Pulse (mung, BARI-6)	503	731
48	80%	80%	3,715	Pulse (mung, BARI-6)	519	691

*Low and high revenue estimates were calculated using the low and high yields from the "typical yield range" provided by the focus group participants.

**According to focus group participants, cropping intensity declines from 2018 to 2021 for Polder No. 47/2 because of the ongoing polder rehabilitation construction activity near the sluice gates.

Approach

The crop revenue approach uses two scenarios of farmer revenues for all 10 polders included in the original Packages 1 and 2. The first is a counterfactual scenario without polder rehabilitation where regular tidal flooding and storm surge events occur at the baseline frequency. The second is the polder rehabilitation scenario with projected increased farmer revenues as the polder rehabilitation reduces storm surge and regular tidal flooding. For both scenarios, we evaluate three types of benefits:

Storm surge protection

Polder rehabilitation enhances protection from the tropical cyclones that periodically flood causing various damage, including flooding cropped areas with saltwater. In the counterfactual scenario without rehabilitation, storm surge damage on cropped areas from cyclones occurs more frequently than in the scenario with rehabilitation. The effects of salinity on crop growth are simulated with a crop model.

Tidal flooding protection

Polder rehabilitation increases the cultivated area by reducing the areas regularly flooded by high tides. In the counterfactual scenario, the risk is too high to invest time and resources to plant in these areas. In the scenario with polder rehabilitation, once the salinity in the soils is reduced to acceptable levels for planting (simulated with a crop model), farmers begin to ramp up production in the previously unproductive land.

Rabi season cropping intensity growth

Tidal flooding is particularly damaging in the Rabi season because rain and river flows that may otherwise reduce saltwater intrusion subside. In Package 1, Rabi season cropping intensity has steadily increased as farmers gain confidence in the newly rehabilitated polders. In the counterfactual scenario, Rabi season cropping intensities remain at the baseline (2018) level, while in the scenario with polder rehabilitation, Rabi season harvested areas steadily increase.

Reduced saltwater intrusion from storm surge and tidal flooding

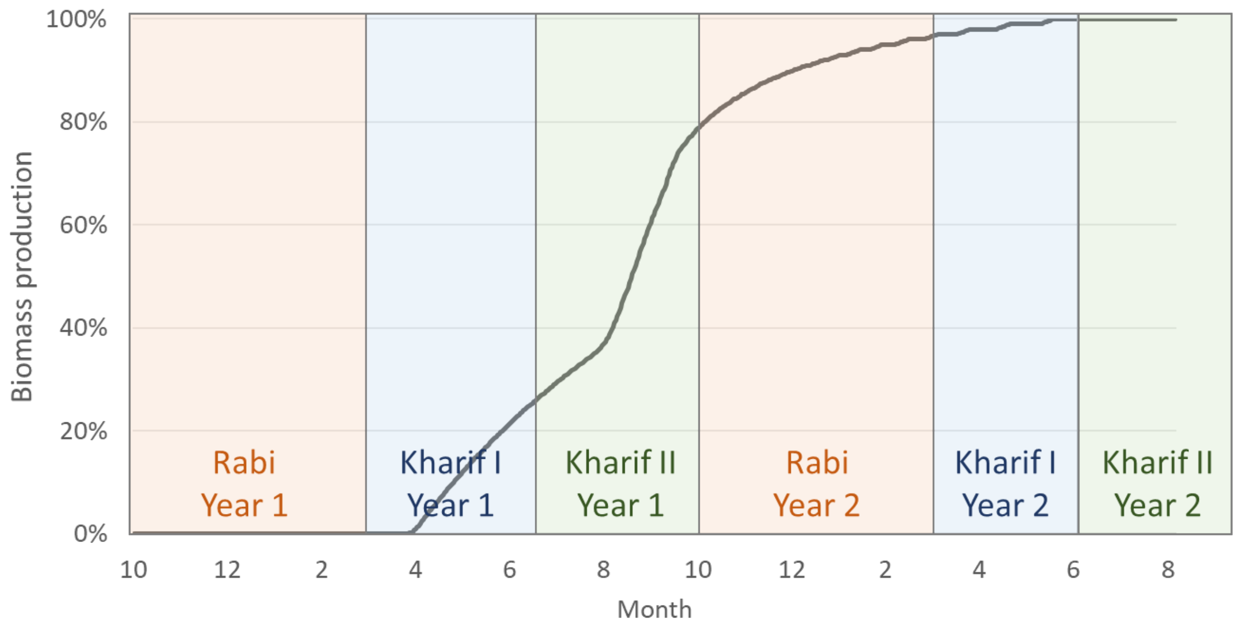
We model the salinity stress on crops caused by storm surge or tidal flood using the AquaCrop model. AquaCrop is a process-driven crop growth simulation model developed by the Food and Agriculture Organization (FAO) of the United Nations.[29] AquaCrop simulates various stresses on crops and has been used in many contexts to simulate salinity stress on crop growth. Salts are transferred downwards in the soil profile by soil water flow from rainfall or irrigation in the macro pores, while salt accumulated in the micro pores of the soil are transferred through a slower diffusive process. Salts can also move upward through the capillary rise when soils are sufficiently dry.[30] The movement of salt in, out, and within the soil profile is solved iteratively using a daily timestep.

Storm surge damages

First, we use the AquaCrop model to simulate a storm surge event from a cyclone in early January that completely saturates a field, and then track salinity stress and crop biomass production potential. For climate conditions, we use a global dataset developed by the Terrestrial Hydrology Research Group at Princeton University.[31] For sea surface salinity levels in January, we use the Soil Moisture Active Passive (SMAP) platform, SSS v4.0 L3 developed by both NASA and Remote Sensing Systems.[32]

High levels of salinity in the soils reduce biomass production potential, which is directly related to crop yield. If biomass production is 0 percent, the crop is unable to grow; at 50 percent, the crop growth is reduced to half; and at 100 percent, there is no impact of soil salinity on growth and yield. Figure 7 shows the biomass production potential over a two-year recovery period after a tidal flood that occurs in the beginning of the Rabi season, October 15, for an irrigated crop that is moderately sensitive to salinity stress such as rice. As shown, crops are unable to grow for the first seven months and are significantly impaired through the first year. At the beginning of the second year, biomass production is only moderately impaired as rains and irrigation water dissolve and drain salt from the root zone. Salt stress becomes insignificant by Kharif-II of the second year, when the field has fully recovered.

Figure 7. Crop Biomass Production Potential during the Recovery Period after a Tidal Flood over Two Years



The data from the farmer focus groups in late 2021 indicate that where polders in Package 1 have been rehabilitated, storm surges have declined, although it is too early to know exactly how much the frequency of these events has changed. To estimate the occurrence of storm surge events with and without the polder rehabilitation, we rely on modeling results reported in Annex 6 of the Project Appraisal Document for the occurrence of a significant storm surge event that inundates the full cultivable area for Polder 35/1. The recurrence interval for such a storm was estimated to be six years for Polder 35/1 and 10 years for the remaining polders in Package 1 without the rehabilitation, and ranging from 55 and 100 years with the polder rehabilitation (see Table 11). We develop an annual expected loss in revenues for the two years that follow the storm surge event by combining the recurrence interval with yield impacts simulated by AquaCrop and cropping intensities for the three seasons.

Table 11. Storm Surge Recurrence With and Without Polder Rehabilitation for Package 1 Polders

	Storm Surge Recurrence	
Polder No.	Without Polder Rehabilitation	With Polder Rehabilitation
32	6	55
33	10	100
35/1	10	70
35/3	10	90
Source: Project Appraisal Document		

Tidal flooding

Although tidal flooding is typically less severe than storm surge, tidal flooding is usually more frequent, with recurrence intervals ranging from around two years to multiple times a year. When these floods occur regularly, their high frequency can sometimes result in more damage than from storm surges.

The Project Appraisal Document indicates that a share of the cultivable land in each polder is regularly inundated by tidal flooding. The document also provides estimates of the areas impacted by polder for all four of the Package 1 polders. The share of cultivable area across these polders are relatively consistent, ranging from 30 percent to 42 percent, with a mean share of 35 percent. Because of the similarities between polders across packages and the somewhat consistent share of land across the four polders in Package 1, we use the mean value of 35 percent of the area regularly inundated from tidal flooding for polders in Package 2. For the counterfactual scenario and baseline, this area is unavailable for planting, constraining revenues to the areas that are not regularly flooded.

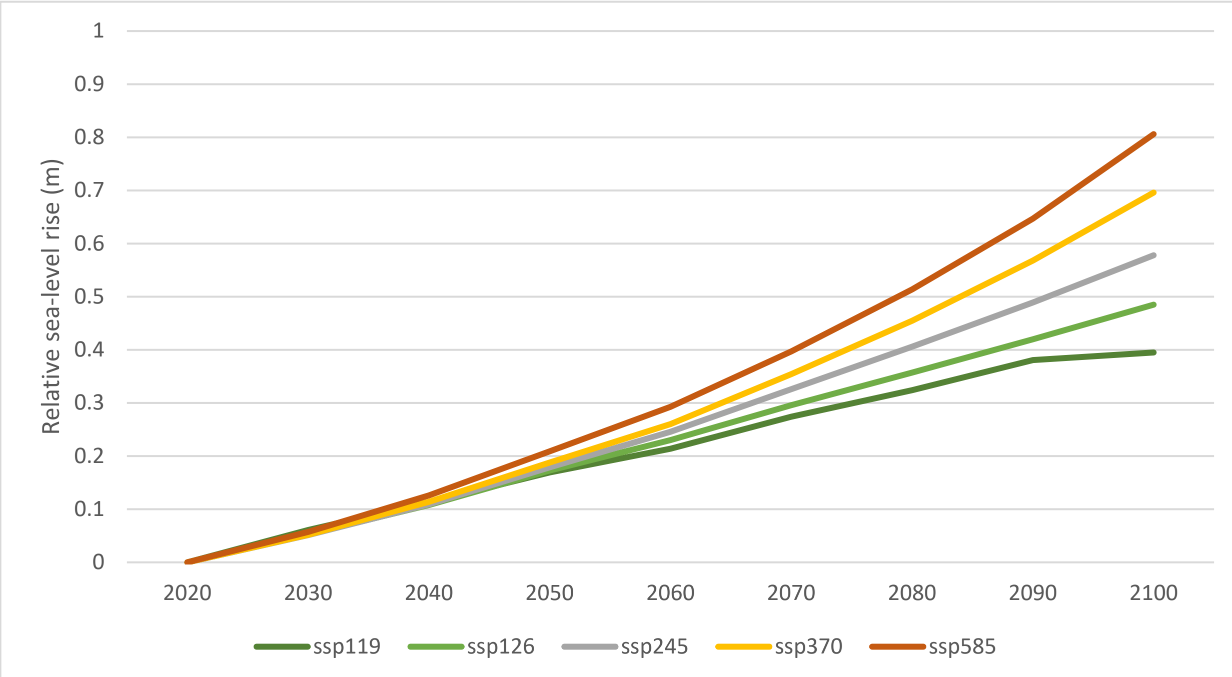
Using the AquaCrop model to evaluate the amount of time it takes before soil salinity of fallow land that was once regularly flooded but is not protected, we find that it would take about three years for the land to recover in coastal Bangladesh. In the polder rehabilitation scenario, once rehabilitation is complete, and after the three-year recovery period, we assume farmers build up to full cultivation during the following three years.

Sea-level rise

Global mean sea-level rise is likely to increase the occurrence and extent of extreme storm surge events and regular tidal flooding in many coastal areas, while atmospheric conditions and warmer ocean temperatures could make tropical cyclones more intense. At a local level, change in mean sea level relative to ground elevations differs regionally, and depends on many factors such as vertical ground movement (subsidence or accretion), isostatic rebound effects from glacial melting, or regional variations in earth's gravitational field. Sea-level rise projections from the latest Intergovernmental Panel on Climate Change Assessment Report (AR6) suggest relative sea-level rise in coastal Bangladesh (at Heron Point) will reach roughly 0.11-0.13 meters in 2040 and 0.38-0.46 meters in 2080 compared to mean sea levels in 2020, across emissions scenarios.[33] Land surface elevations in the Bengal Delta are generally below 4 meters[34], so even small changes in mean sea level can have drastic consequences.

This being the case, we are unable to model the effect of sea-level rise on the polder rehabilitation projects because of several data limitations and uncertainties. First, georeferenced spatial information about the polder boundaries and embankments are not available. Second, topographic datasets with vertical resolution high enough to determine changes in inundated areas are not yet available. Most datasets available are only available at 1-meter increments. In such a flat area with mean sea level changes less than 1 meter, detailed topographic data is necessary. While a recent study attempts to provide a higher resolution topographic dataset,[35] in situ measurements reveal an accuracy of about 1.5 meters. Third, and most importantly, an assessment of sea-level rise effects for the polder areas requires information on the embankment degradation with details on the heights of the places along the embankment where sea waters are encroaching croplands or potential cultivable areas with rehabilitation.

Figure 8. Relative Sea Level Change Projection for Coastal Bangladesh



Changes in harvested area during the Rabi season

Cropping intensity collected in the focus groups indicates that in Package 1, where bolder rehabilitation is complete, Rabi season harvested areas have steadily increased as farmers gain more confidence in the polder's ability to protect from soil salinity. This includes Polders 32, 33, and 35/1. Among these polders, the average increase in harvested area is 12 percent of the total cultivable area per year, ranging from 8 percent to 15 percent. While Kharif-I harvested areas are often less than 100 percent, intensities may not increase with the polder rehabilitation based on the reasons noted above, and in particular, that the cropping intensity associated with Package 1 polders did not change for 2018–2021.

We assume the trend continues in the Rabi season for these three polders, up to a maximum of 100 percent of the total cultivable area., We use the same approach for the remaining polders, but assume the annual increase will be the average annual increase of the three polders with functional protection from tidal flooding at 12 percent per year, since the polders for Package 2 are in aggregate similar to the polders in Package 1. Some of the polders are already harvesting nearly or exactly 100 percent of the cultivable area in the Rabi season. For example, Polder 43/2C is already harvesting 100 percent, and so will not benefit from this effect.

Estimating the impacts on farmer revenues

The impacts to farmer revenues are estimated differently across the two packages.

- For Package 1, where the most data are available, we use estimated storm surge recurrence intervals with and without polder rehabilitation and estimated areas regularly inundated by tidal flooding for each of the four polders. For increased harvested area in the Rabi season, we use increases in cropping intensity data collected during focus groups in late 2021. Benefits for the Rabi season represent actual benefits from 2018 to 2021 compared with 2018, and these are projected by extrapolation after 2021.

- For Package 2, we rely on the Package 1 average storm surge recurrence interval with and without polder rehabilitation, the share of cropland regularly inundated by tidal floods, and estimate increases in cropping intensity in the Rabi season. Benefits for this package are projected to start after the completion year in 2023.

Sub-Appendix 2D. Methodology for Applying the Joint Impact Model (JIM)

Increases in agricultural revenues from CEIP-I will lead to regional job creation, increased value added and tax revenues, and other economic benefits. To estimate these benefits, we use the Joint Impact Model (JIM), which estimates the direct and indirect economic, employment, and environmental impacts of a portfolio of investments.[36] To do so, JIM uses publicly available macroeconomic statistics from sources such as the Global Trade and Analysis Project (GTAP), the International Labour Organization (ILO), the World Bank, and the International Energy Agency (IEA).

JIM has three key categories of impact indicators: employment, value added, and greenhouse gas (GHG) emissions.[37] The employment indicator considers the number of working people (above age 15) who produce goods or services for pay or profit. This impact category includes the subcategories of female employment, formal employment (all working-aged people hired under an established working agreement), informal employment (working-aged people employed without a working agreement), and youth employment (all working-aged people between 15 and 25 years old). The value-added impact category considers the monetary value of the sum of salaries (net wages paid to all full-time and part-time employees), taxes (all transfers to the government), and savings (value of the organization's profits).

JIM also considers the scope of the quantified impact, across the following categories.

- **Direct:** impacts at the client company or project;
- **Induced:** impacts associated with the client company or project's employees, suppliers (and their suppliers), spending their wages;
- **Supply chain:** impacts at the client company or project's suppliers and their suppliers.

Endnotes

[1] Based on data from 2018 and 2021. According to the October 2022 Implementation Status & Results Report, cropping intensity in the project sites increased from 140 percent from baseline data in April 2013 to 186 percent in August 2022. This percentage represents the total gross cropped area (single, double, and triple crops) divided by total cultivable land in a cropping season for ten selected polders of CEIP-I expressed in % (the number of crops a farmer grows in a given agricultural year on the same field).

[2] ADB. Concept Paper, pg. 1.

[3] ADB. Bangladesh: Coastal Towns Environmental Infrastructure Project – Project Data Sheet.

[4] World Bank. Coastal Embankment Improvement Project - Phase I (CEIP-I).

[5] ADB. Report and Recommendation of the President to the Board of Directors, pg. 1.

[6] ADB. Concept Paper, pg. 1.

[7] World Bank. Project Appraisal Document for Coastal Embankment Improvement Project Phase 1.

[8] World Bank. Project Appraisal Document for Coastal Embankment Improvement Project Phase 1.

[9] CIF. Bangladesh.

[10] World Bank. Project Appraisal Document for Coastal Embankment Improvement Project Phase 1, pg. 17.

[11] The CIF PPCR project ID for the project is XPCRBD002A.

[12] Bangladesh – Coastal Embankment Improvement Project – Phase I (CEIP-I): P128276 – Implementation Status Results Report: Sequence 03 (English). Washington, D.C.: World Bank Group. Available at: http://documents.worldbank.org/curated/en/274731468203380251/Bangladesh-Coastal-Embankment-Improvement-Project-Phase-I-CEIP-I-P128276-Implementation-Status-Results-Report-Sequence-03

[13] The value of the contract for Package 2 is not clearly stated. However, the total budget for polder rehabilitation was $286 million (Component A1, as described in Appendix 1) and the value of the contract for Package 1 was $100 million. Thus, we estimate that the value of the contract for Package 2 was $186 million.

[14] Kazi, Swarna. Disclosable Version of the ISR – Coastal Embankment Improvement Project – Phase I (CEIP-I) – P128276 – Sequence No: 11 (English). Washington, D.C.: World Bank Group. Available at: http://documents.worldbank.org/curated/en/644111556751944620/Disclosable-Version-of-the-ISR-Coastal-Embankment-Improvement-Project-Phase-I-CEIP-I-P128276-Sequence-No-11

[15] Bangladesh Water Development Board Ministry of Water Resources. Environmental and Social Framework: Executive Summary, pg. 2.

[16] PPCR Project/Program Approval Request for Coastal Embankment Improvement Project Phase I (CEIP-I).

[17] For an overview of Bangladesh's cropping seasons, see: Hossain, M.S., L. Qian, M. Arshad, S. Shahid, S. Fahad, and J. Akhter. 2018. "Climate Change and Crop Farming in Bangladesh: An Analysis of Economic Impacts." *International Journal of Climate Change Strategies and Management* 11 (3): 424–40. doi:10.1108/IJCCSM-04-2018-0030.

[18] Since the rehabilitation is not complete for Package 2 polders, the average annual increase of 12 percent is based only on the Package 1 polders. It is based on an average year-on-year change starting with the year the farmers noticed improved performance of the embankment post-rehabilitation.

[19] Sheladia Associates, Inc., CEIP-I Baseline Survey Report cum Midline Survey Report, July 2021.

[20] It is our understanding that CIF also used the JIM to analyze the economic implications of the polder investments themselves (i.e., short-term construction benefits) in a separate analysis.

[21] Sheladia Associates, Inc., CEIP-I Baseline Survey Report cum Midline Survey Report, July 2021.

[22] [22] Sheladia Associates, Inc., CEIP-I Baseline Survey Report cum Midline Survey Report, July 2021.

[23] Kazi, Swarna. Disclosable Restructuring Paper – Coastal Embankment Improvement Project – Phase I (CEIP-I) – P128276 (English). Washington, D.C.: World Bank Group, January 2020. Available at: http://documents.worldbank.org/curated/en/358001578985595693/Disclosable-Restructuring-Paper-Coastal-Embankment-Improvement-Project-Phase-I-CEIP-I-P128276

[24] Ishtiaque, Asif et al., "Robust-yet fragile nature of partly engineered social-ecological systems: a case study of coastal Bangladesh," *Ecology and Society*, Sept 2017, Vol 22, No.3.

[25] Sheladia Associates, Inc., CEIP-I Baseline Survey Report cum Midline Survey Report, July 2021.

[26] The 2021 Baseline/Midline Survey Report was originally intended as a pre/post survey of affected communities. A survey was fielded in 2016 and 2018, which were the original pre/post years. However, due to project delays, not enough construction was complete in 2018 to see project benefits at that time, and the 2018 data is characterized as a re-baselining. In this case study, we use 2018 as the baseline year for quantitative analyses.

[27] Kazi, Swarna (2021) Disclosable Version of the ISR – Coastal Embankment Improvement Project – Phase I (CEIP-I) – P128276 – Sequence No: 15 (English). April 10, 2021. Washington, D.C.: World Bank Group. Available at http://documents.worldbank.org/curated/en/397921618048199822/Disclosable-Version-of-the-ISR-Coastal-Embankment-Improvement-Project-Phase-I-CEIP-I-P128276-Sequence-No-15

[28] Kazi, Swarna (2018) Disclosable Version of the ISR – Coastal Embankment Improvement Project – Phase I (CEIP-I) – P128276 – Sequence No: 10 (English). November 14, 2018. Washington, D.C.: World Bank Group. Available at http://documents.worldbank.org/curated/en/102921542155493836/Disclosable-Version-of-the-ISR-Coastal-Embankment-Improvement-Project-Phase-I-CEIP-I-P128276-Sequence-No-10

[29] See https://www.fao.org/aquacrop/

[30] For all processes and equations, see Chapter 3 of the AquaCrop documentation available here: https://www.fao.org/fileadmin/user_upload/faowater/docs/AquaCropV40Chapter3.pdf

[31] Process for climate development was first described in Sheffield et al. (2006). Sheffield, J., G. Goteti, and E. F. Wood, 2006: Development of a 50-yr high-resolution global dataset of meteorological forcings for land surface modeling, J. Climate, 19 (13), 3088-3111

[32] See Meissner et al. (2018) for more details. Meissner, Thomas, Frank J. Wentz, David M. Le Vine (2018) The Salinity Retrieval Algorithms for the NASA Aquarius Version 5 and SMAP Version 3 Releases. Remote Sens., 10(7), 1121; https://doi.org/10.3390/rs10071121

[33] Using sea-level rise projections available here: https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool

[34] Krien, Y.; Mayet, C.; Testut, L.; Durand, F.; Tazkia, A.R.; Islam, A.K.M.S.; Gopalakrishna, V.V.; Becker, M.; Calmant, S.; Shum, C.K.; et al. Improved Bathymetric Dataset and Tidal Model for the Northern Bay of Bengal. Mar. Geod. 2016, 39, 422–438

[35] Khan, Md Jamal Uddin, MD Nazmuddoha Ansary, Fabien Durand, Laurent Testut, Marufa Ishaque,Stéphane Calmant, Yann Krien, A.K.M. Saiful Islam, and Fabrice Papa, 2019. High-Resolution Intertidal Topography from Sentinel-2 Multi-Spectral Imagery: Synergy between Remote Sensing and Numerical Modeling. Remote Sens. 2019, 11(24), 2888; https://doi.org/10.3390/rs11242888

[36] For more information, see: Steward Redqueen. Joint Impact Model: User Guide. November 2021. Available at https://www.jointimpactmodel.org/_files/ugd/7aa894_4dfb06af41034d0f85d5316f1cc399f5.pdf.

[37] We did not use JIM to calculate GHG impacts of increased agricultural production. Analysis of the full suite of GHG benefits versus negative impacts of the CEIP-I project would require extensive modeling that is out of scope for this case study.

3. Brazil Deep-Dive Case Study: Improving Agricultural Livelihoods through Better Land Management and Low Carbon Agricultural Practices

Project Details	Funding
Name: Brazil Investment Plan (BIP) projects: Sustainable Production in Areas Previously Converted to Agricultural Use Project (Support for Brazil's ABC Plan for Low Carbon Agriculture[1]; also known as the "ABC project"); Integrated Land Management (ILM) project; and Dedicated Grant Mechanism (DGM) Project (community engagement in climate change programming) **Country:** Brazil **CIF Program Area:** FIP **Multilateral Development Bank (MDB) approval:** 2012 **Effective since:** July 2014 **Expected closing:** 2023 **MDB:** World Bank	**Total Value:** $37.81 million grant **CIF:** $37.81 million grant **Co-financing:** In kind only **Instrument type:** Grant **Sector:** Public

Key Highlights

- This case study evaluates the development impacts (DIs) of improved land and agricultural management, and low carbon agricultural practices, including economic impacts of improved agricultural production and farmer livelihoods in the Cerrado biome, and environmental benefits including increase in pollinator habitat and carbon sequestration.
- Most quantified DIs are from the ABC project (not the broader ABC Plan of the government), which has five years of implementation experience. The ILM project launched in 2018. The DGM project is focused more on community engagement and empowerment generally, and less on quantifying specific agricultural outcomes.
- CIF contributed 100 percent of the projects' combined total value of $37.81 million.

Topline Findings on Development Impacts

- **Improved land management:** The ABC project resulted in a direct increase of 93,844 hectares of agricultural tracts using improved management practices, over nearly 3,000 farms. The ABC project also increased the land area under regulated, environmental protection by 34 percent. The ILM project introduced low-carbon agricultural practices on more than 11,000 ha, and the DGM project extended sustainable landscape management practices to 831 ha.
- **Expansion of pollinator habitat:** If all pasturelands in the area were restored using practices promoted by FIP, pollinators would have access to 75 percent of the soy crops and nearly all of the coffee crops in the biome. This may improve crop productivity and/or reduce the need for

farmers to provide replacement pollination services for their crops. This information was obtained through the modeling work conducted by the IEc team.

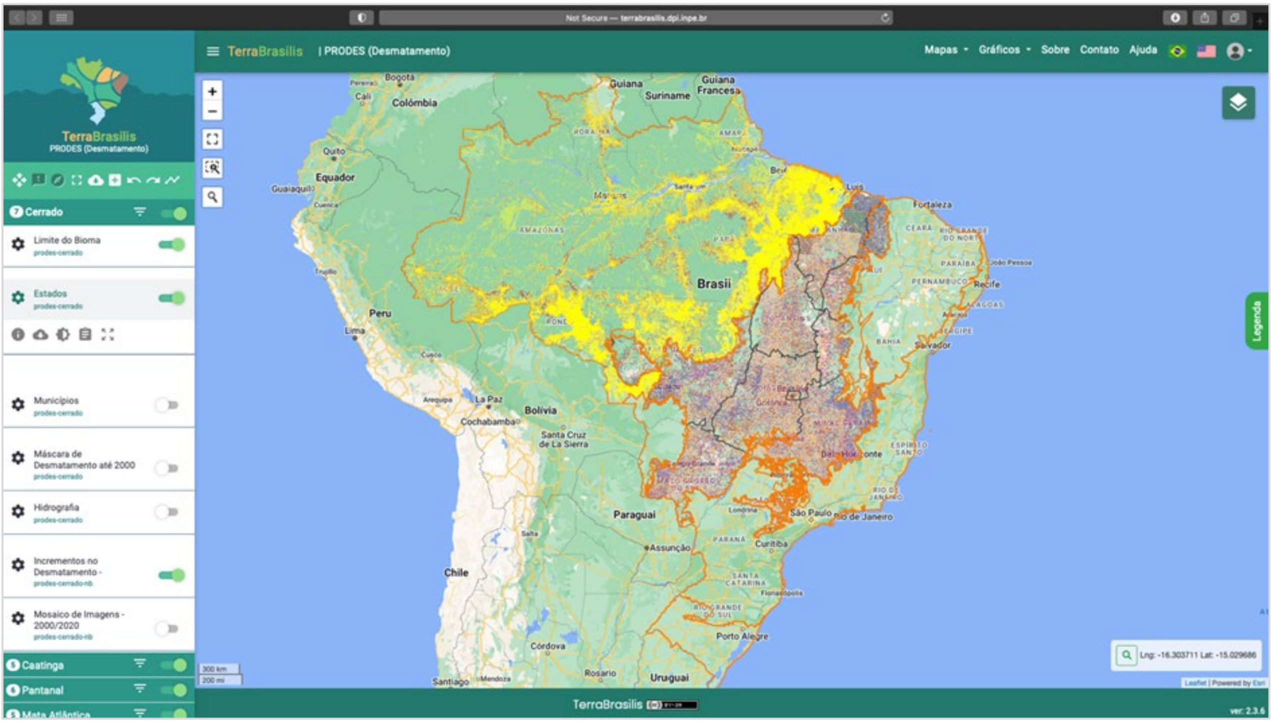
- **Carbon sequestration:** A net carbon sequestration of 6.6 million tons CO_2e was achieved by the ABC projects, compared with a control group that did not adopt improved land management practices.
- **Agricultural productivity:** Cattle productivity increased significantly on participating ranches; stocking rates grew from 0.7 to 2.5 animals per hectare; cattle weight gain increased from 400 to 900 grams per day; and time to slaughter decreased from 36 to 19 months.
- **Farmer livelihoods:** ABC producers had an average income growth 2.7 times higher than producers in a control group, and a 24–40 percent reduction in total costs.
- **Gender-related benefits:** By the end of the ABC project, 25–30 percent of participating farms were led by women or had strong participation by women. Evaluations indicated that women's involvement had a positive influence—particularly on the speed of implementation. DGM projects were particularly successful in attaining their gender empowerment objectives, due to the specific focus of activities in this area.

Climate Investment Context and Overview

Brazil is the largest country in Latin America and the fifth largest in the world, with an area of 851.5 million hectares.[2] The Cerrado biome, a tropical savannah with a variety of ecosystems, covers about 24 percent of Brazil's land area—some 2.04 million km^2—in central Brazil, south and east of the Amazon region.[3] The Cerrado is home to a population of 26.4 million people (13 percent of the country's population) and accounts for 32 percent of all the rural properties in Brazil. The Cerrado biome has strategic importance for environmental and economic reasons, and also for food security.

Across the 11 states in the Cerrado biome, the number of rural properties is estimated at 1.032 million, including about 795,000 family farms. About 10 percent of all rural properties are managed by women.[4] Overall, the Cerrado has some of the largest land holdings in the country, with an average area of 397 hectares.[5]

Figure 1. Cerrado Biome



Source: TerraBrasilis, with biome border indicated in orange and increments of deforestation indicated in color range, yellow tones earlier (2002) and darker tones later (2022).

The Cerrado retains substantial carbon stocks, notably below ground, with values of 15.23–225.09 tons of carbon per hectare (tC/ha), depending on the specific land cover.[6] It is also extremely rich in its biodiversity, with some 40,000 different species of flora already catalogued and a rich fauna as well, though only a small fraction has been documented.[7]

Rapid expansion of cattle ranching, especially followed by the mechanized production of soybean, has driven deforestation in the Cerrado. As of 2018, 50 million head of cattle, almost 33 percent of the national herd, lived on 58 million hectares of pasture in the Cerrado, based on data from TerraClasse. High rates of deforestation and forest degradation in the Cerrado biome account for 8 percent of Brazil's greenhouse gas (GHG) emissions.[8] Between 2000 and 2010, deforestation and burning of Cerrado areas resulted in average annual emissions of about 335.5 million tons CO_2e (including CH_4 and N_2O).[9]

Agricultural expansion and deforestation have also caused environmental degradation and increased the social vulnerability of Indigenous Peoples and traditional communities (IPTCs). Impacts include poverty, food insecurity, social conflicts over scarce resources, migration of young people, and weakened social ties, among others. This is a consequence of both lawful and unlawful reductions in the stock of open lands traditionally used by IPTCs, resulting habitat change and fragmentation, as well as resource extraction by encroachers. Population growth and social exclusion have also led to the overexploitation of some resources by IPTCs themselves.[10]

Purpose and Scope of the Case Study

The major challenge in the Cerrado is how to meet ever-growing demand for agricultural commodities while sustaining rural livelihoods and protecting ecosystems and the critical services they provide.[11] More efficient land use could enable Brazil to increase crop productivity without increasing deforestation and GHG emissions. However, prior to CIF-financed interventions, rural farmers and ranchers were unaware of agricultural practices that have both productivity and environmental benefits. This challenge was compounded by weak farm management skills, market access difficulties, lack of minimum price guarantees, and inadequate training and technical assistance for small and mid-sized producers.

This case study evaluates the development impacts (DIs) of improved land and agricultural management and low carbon agricultural practices introduced through CIF investments. The main focus is on the economic and livelihood impacts of boosting productivity, as well as environmental benefits such as an increase in pollinator habitat (a lynchpin ecosystem service) and carbon sequestration. Additional DIs examined include benefits to women and vulnerable populations, and local and institutional capacity building. CIF aims to use the results to further optimize future programming, as lessons from this case study can help maximize DIs in adaptation projects in other developing countries.

CIF's programmatic approach fosters collaboration among government ministries, civil society, Indigenous Peoples, the private sector, and multilateral development banks (MDBs). In a country-led process, CIF works with these stakeholders to translate national development and climate strategies, including Nationally Determined Contributions, into a CIF action plan of long-term, sequenced investments that reinforce one another and link to other critical activities.

The Brazil Investment Plan (BIP) under the Forest Investment Program (FIP) was designed to generate synergies between different agencies and stakeholders at the biome level in order to improve the sustainability and efficiency of forest management and land use in the Cerrado, and is implemented under two thematic areas: (i) improving environmental management in previously converted areas; and (ii) producing and disseminating environmental information at the biome scale. This case study focuses on three components of the BIP, as shown in Table 1 on the following page: the Sustainable Production in Areas Previously Converted to Agricultural Use Project (ABC project), the Integrated Land Management (ILM) project, and the Dedicated Grant Mechanism (DGM) project.

There are five additional projects that are not included in this case study, focused on developing systems to prevent forest fires and monitor vegetation cover in the Cerrado; providing forest information to support the public and private sectors in management initiatives; environmental regularization of rural lands in the Cerrado; silviculture with Macaúba palm oil (the focus of Case Study 4); and the Investment Plan Coordination Project, supporting the entire portfolio. Each project in the BIP contributed to a coordinated effort by funding investments and activities designed to support actions at different levels. In addition to addressing the different aspects of interagency coordination, the Plan also contributed to resolving operational, regulatory, and management challenges.

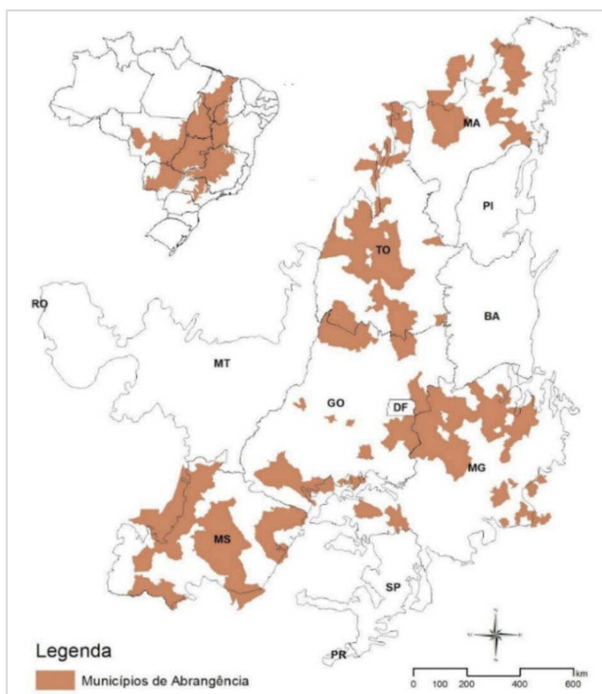
Table 1. FIP Brazil Selected Project Components

Project	Description	Dates	Total Funding	CIF Funding
ABC Project	Promoted the adoption of selected sustainable low-carbon emissions agricultural technologies by mid-sized producers in the Cerrado region.	2014–2019	$10.31 million* grant	$10.31 million grant
DGM project	Worked to strengthen the engagement of Indigenous Peoples and traditional communities in the Cerrado in FIP, REDD+, and similar climate change-oriented programs at the local, national, and global level.	2015–2021	$6.5 million grant	$6.5 million grant
ILM Project	Works to strengthen the adoption of environmental conservation and restoration practices, and low-carbon emission agricultural practices in selected watersheds of the Cerrado biome.	2019–2023	$21 million grant	$21 million grant
Total				$37.81 million grant
* The original planned government co-financing of $0.51 million was considered to be in-kind contributions from SENAR infrastructure, staff, and operational costs.				

ABC project

The ABC project was a pilot with an experimental design aimed at supporting the national Low Carbon Agriculture (ABC) Plan (see Sub-Appendix 3A for more details) by evaluating methodologies for agricultural extension. It directly addressed the problem of the insufficient adoption of low-carbon technologies by producers in the Cerrado, including inadequate knowledge, resources, and missing behavioral incentives. The actions included no-till agriculture, restoration of degraded pastures, commercial forest planting, biological nitrogen fixation, treatment of animal wastes, and implementation of the crop-livestock-forest approach.

FIP-ABC Coverage



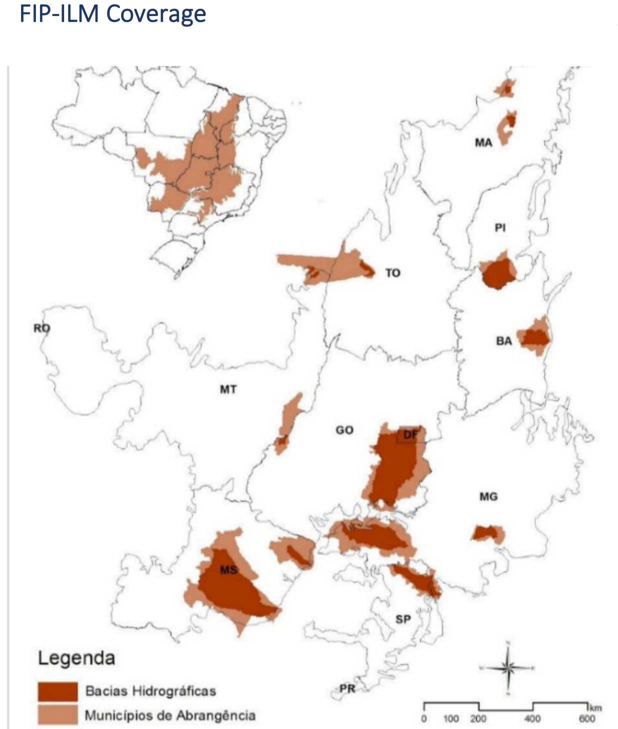
Source: NSC (2022)

ILM project

The Integrated Landscape Management (ILM) project objective is "to strengthen the adoption of environmental conservation and restoration practices, and low-carbon emission agricultural practices in selected watersheds of Brazil's Cerrado Biome." It is implemented in 53 pre-selected watersheds in nine states (Bahia, Goiás, Maranhão, Minas Gerais, Mato Grosso do Sul, Mato Grosso, Piauí, São Paulo, and Tocantins).

The ILM project distinguishes itself from the predecessor ABC project, through its more holistic focus on the development of capacities at the national and local levels to plan and implement a landscape approach in the selected watersheds. The development and implementation of spatial planning and monitoring platforms are critical to integrating information and contributing to decision-making on landscape management.

FIP-ILM Coverage



Source: NSC (2022)

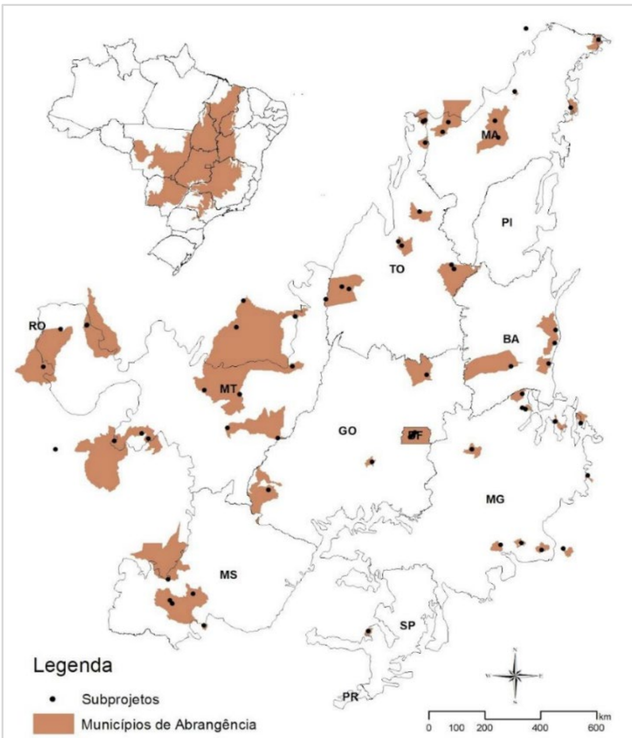
DGM project

The DGM project objective was to (i) strengthen the engagement of the Cerrado Biome's IPTCs in FIP, REDD+ and similar climate change-oriented programs at the local, national, and global level, and (ii) contribute toward improving livelihoods, land use, and sustainable forest management in their territories. The project had three components: 1) community support initiatives, 2) technical assistance to relevant IPTC organizations, and 3) project management, monitoring, and evaluation. The first component included a competitive grant facility. Projects were selected on a number of criteria, including alignment with FIP and DGM objectives, socio-environmental relevance, cultural adequacy, community support, and sustainability. Supported activities included:

- Sustainable forest and land use management systems as well as community-led forest landscape restoration;
- Seedling production for the maintenance of native and threatened species and varieties;
- Agroforestry production systems and agro-ecological tillage practices by applying indigenous/traditional knowledge and new technologies;
- Collection, value-added processing, and commercialization of nontimber and agricultural products;
- Indigenous and traditional water, soil and landscape management practices, including the recovery of degraded areas and the protection of water sources;

- Livelihood diversification for improved nutrition, food security, and quality of life; and
- Revitalization of cultural values and traditional knowledge.[12]

FIP-DGM Coverage



Source: NSC (2022)

The first call for subprojects was published in February 2016, and the second in August 2017. A third call was dropped due to the large number of subprojects already selected after the first two calls. Subprojects varied widely by thematic lines, with 60 community initiatives and four projects supporting IPTC networks. Of the 60 community initiatives, 46 supported natural resource management, 11 were market oriented, and three focused on emergency response. Most subprojects nevertheless covered multiple thematic lines. Overall, 88 projects were completed.

Development Impact Pathways and Case Study Focus

The project objectives, as stated in project documents, are to deploy integrated land management practices and low carbon agricultural approaches, along with significant investment in local community engagement, to improve farm productivity and farmer livelihoods while sequestering carbon and producing co-benefits from enhanced ecosystem services, including expanded pollinator habitat. Impact pathways are shown in the impact pathway model in Figure 2.

- The **dark blue boxes** indicate the DIs quantitatively assessed in the case study: adoption of low carbon agricultural technologies and conservation and restoration practices; increased farm/rancher productivity and sales; increased employment; economic and social benefits for women; sustainable agricultural intensification; land restoration and protection of critical habitats against deforestation; ecosystem services restored (i.e., pollination); legal reserves and areas of permanent preservation established; and increased carbon sequestration.

- The **light blue boxes** indicate DIs qualitatively assessed in this case study, including strengthening of the local value chain for restoration and natural resources management; strengthened coordination and governance; increased knowledge about the Cerrado Biome; replication of interventions; and decreased vulnerability and increased capacity of IPLCs.
- The **gray boxes** identify potential DIs not assessed due to lack of information; these include poverty alleviation; food security; and diversified livelihoods and subsequent increase in economic resilience.

Figure 2. Impact Pathways for Low Carbon Agriculture and Integrated Landscape Management

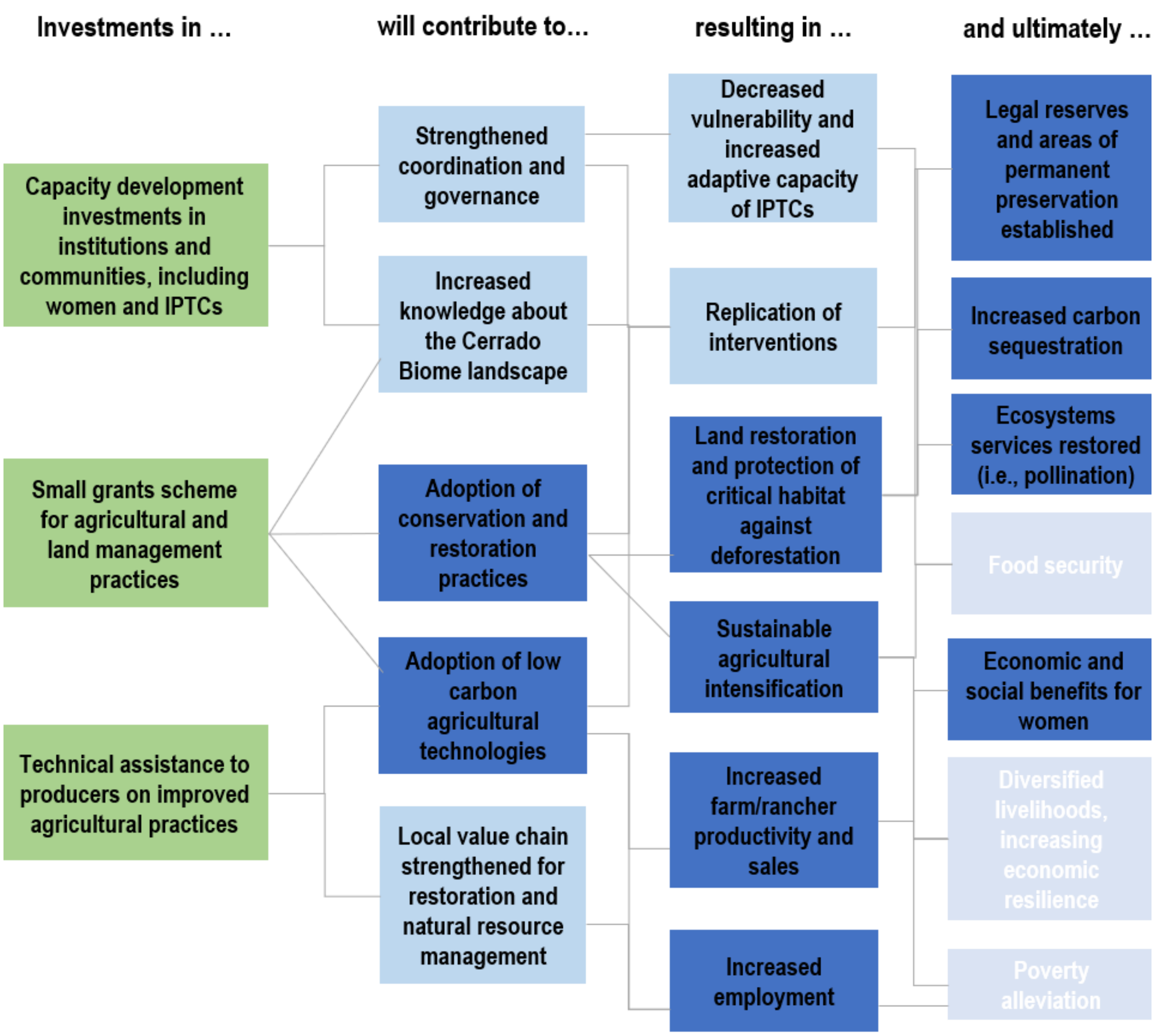


Table 2 shows the extent to which different DIs are noted in project documents as potential outcomes and/or are actively tracked and measured. DIs that are tracked by the project but are not addressed in this case study (and appear as gray boxes in impact pathway diagrams) are premature to assess.

Table 2. Brazil FIP DIs

DI	In Project Documents?	Tracked by Project?
ENVIRONMENTAL		
Land brought under improved agricultural practices	Yes	Yes
Land brought under regulated environmental protection	Yes	Yes
Carbon sequestration	Yes	Yes
Protection of critical habitats/expansion of pollinator habitat	No	No
ECONOMIC		
Increased agricultural productivity	Yes	Yes
Increased farmer income	Yes	No
Increased employment	Yes	Yes
SOCIAL (cross-cutting)		
Women's participation in sustainable agricultural activities	Yes	Yes

Stakeholders

ABC project

The focus of the ABC project were small to mid-size producers in the Cerrado, who would have faced great difficulties to access the technological know-how without government assistance, but at the same time were ineligible for other public programs promoting sustainable agriculture among smallholders and the rural poorest. Eighty-two percent of the producers were cattle ranchers, with the remaining 18 percent composed of producers working in agriculture, horticulture, forestry, and other areas.[13] The ABC project was executed by the National Rural Learning Service (Serviço Nacional de Aprendizagem Rural, SENAR); the Ministry of Agriculture, Livestock, and Food Supply (MAPA); and the Brazilian Agricultural Research Corporation (EMBRAPA), and it worked closely with state agriculture and livestock agencies, commercial banks, rural producer cooperatives and associations, NGOs, and bilateral partners.

ILM

The focus of the ILM project is the landholders living in the selected watersheds. The ILM project works closely with the SFB; MAPA; the National Institute for Space Research (Instituto Nacional de Pesquisas Espaciais, INPE), a research institution associated with MCTIC; EMBRAPA; and SENAR.

DGM

The DGM project was implemented by the Center for Alternative Agriculture of Norte de Minas (CAA/NM). The main beneficiaries of the DGM project were IPLCs and their representative organizations in the Cerrado. The Cerrado is home to 41 Indigenous Peoples and a multitude of traditional local communities, including quilombola communities (ethnically defined peasant communities, but no longer with an official historical connection to slavery), extractive populations, and agricultural and pastoral communities dependent on specific surrounding ecosystems.[14]

Data sources

The main DIs explored include agricultural productivity, improved farmer livelihoods, improved land management practices, expansion of pollinator habitat (a key ecosystem service), carbon sequestration, and improvements in the roles of women and other vulnerable populations. See Table 3 below for a summary of the explored DI, metrics, and methods.

Table 3. DIs, Metrics, and Methods

DI	Metric /KPI	Method of Assessment
ENVIRONMENTAL		
Land brought under improved agricultural practices	Hectares	Project M&R
Land brought under regulated environmental protection	Hectares	Project M&R
Carbon sequestration	tCO_2e	EMBRAPA estimates
Protection of critical habitats/expansion of pollinator habitat	% of soy and coffee crops with pollinator access	Ecosystem services modeling
ECONOMIC		
Increased agricultural productivity	Cattle: animals/ha; average weight of animals; time to slaughter (days) Crops: increased quantity processed; increased sales due to increased quality	Project M&R
Increased farmer income	% income growth, total income growth	ABC project impact evaluation
Increased employment	Number of individuals, disaggregated by gender	ABC project impact evaluation
SOCIAL (cross-cutting)		
Women's participation in sustainable agricultural activities	Metrics disaggregated by gender; hectares, number and % of participating farmers; % of farms where women influence decision-making participation in community organizing	Project M&R

Measuring these DIs was feasible to explore given the maturity of the project, the project's sphere of influence, and the data (modeling and interviews) available. Along with the modeling described in Sub-Appendix 3B, the analysis included a review of project documents and interviews. Data were available from documents explaining the nature and objectives of the project. Key documents reviewed included investment plans, project appraisal documents, grant contracts, online financial and results data, implementation completion and results reports, as well as evaluation reports, where available. Other data sources include contextual documents, journal articles, reports, and news articles.

Interviews were conducted with key representatives from the ABC, ILM, and DGM projects. Due to the high number of DGM-funded subprojects, five DGM subprojects (projects 42, 120, 61, 250 and 129) were selected for deeper analysis. Data collection also included capturing the voices of final beneficiaries—through interviews as well as the analysis of related electronic recordings, notably of the selected DGM subprojects. The IEc team conducted a total of 22 interviews with key stakeholders from 14 organizations (see Sub-Appendix 3C) and participated in two consultation workshops. Efforts were made to coordinate with other ongoing evaluation efforts, to reduce duplication and the burden on stakeholders. This included the participation of the evaluation team in two consultation sessions organized in the framework of these other efforts. The consultation workshops were attended by a total of 55 participants (see Sub-Appendix 3C for detailed lists of attendees). Additional adjustments were required due to COVID-19 restrictions, notably those pertaining to Indigenous communities.

Development Impacts

Environmental impacts

Improved land management practices

The selected FIP investments all had either a demonstrated or expected impact on the sustained improvement in land management practices.

The ABC project rigorously demonstrated the effectiveness of a combined strategy of training (CAP) and technical assistance (ATEG) on the uptake and retention of low-carbon agricultural management practices. In the rigorous, experimental design that underlay the project, one beneficiary group received only training, one beneficiary group received training and technical assistance (TA), and a pure control group was not exposed to any treatment. The project provided a total of 56 hours to groups of 20 participants on good farm management practices, as well as key principles of low-carbon agriculture technologies, including self-selection into a single low-carbon technology module. Those randomly selected for TA also received monthly four-hour visits on their own farm by field technicians, for an average period of 20 months, covering issues across the entire production cycle.

For the ABC project, the total land area of participating producers was 1,069,090 hectares, with a target of 160,364 ha under low-carbon technologies. The impact evaluation study estimated a direct increase of 93,844 hectares in project areas under ABC technologies (sum of 42,588 ha for CAP group and 51,256 ha for CAP+ATEG group).[15]

The indirect effect, computed as areas under indirect interventions, meaning the positive spillovers that the application of ABC technologies on one portion of farmland creates on the entire farm (e.g., indirect recovery through harrowing and seeding) was 151,204 ha for the CAP group and 133,464 ha for CAP + ATEG for a total of 284,668 ha.

These figures were confirmed by the recently concluded process component of the overall BIP process evaluation conducted by the Group Natureza, Sociedad e Conservação (NSC). Based on calculations by the overall BIP process evaluation, the ABC project led to a 6.4 percent increase in the area where technologies were adopted for the CAP group and a 16 percent increase in the CAP + ATEG group.

The ABC project also increased the land area under regulated, environmental protection. The ABC project also experienced a 33.9 percent increase in forest conversation areas (Legal Reserve + Permanent Protection Areas = 192,534 hectares). This included a 7.6 percent increase in riparian forest and a 14.2 percent increase in watershed recovery within CAP + ATEG and 2 percent increase within CAP. Supervision missions confirmed that the implementation of the ABC project had also resulted in less pressure on legal reserves and permanent preservation areas.[16]

Once the ABC technologies were implemented, several positive effects on pasture recovery were recorded, such as increased understanding that pastureland is a production system that requires correct management to increase productivity, similar to other agricultural land. Some behavior changes documented included stopping the use of fire and avoiding the opening up of new areas for pasture. Pasture recovery was perceived as instrumental to ensuring not only environmental benefits, but also ensuring adequate amounts of quality forage for milk production.

The ILM project expects similar results, but also with broader benefits on landscape management across the selected watersheds. The ILM project aims to introduce low carbon emission agricultural practices on 100,000 hectares of land by project end, by 4,000 farmers, 25 percent being women. It also aims to restore 7,000 hectares of land by project end, with a total of 3,500 landholders, 25 percent being women, benefiting directly from project support in this regard.[17] Based on the latest data from the process evaluation, 688 farmers, with 22 percent being women were applying integrated landscape management on approximately 11,000 hectares by November 2021.[18]

Though much smaller in its scale, the DGM project also recorded sustainable land management practices, with impacts beyond its original estimates. By October 2021, the DGM project had established sustainable landscape management practices on 659 hectares, which surpassed the final project target of 600 hectares.

Expanded and restored ecosystem services

Improved agricultural and land management practices also improve environmental services, including expansion of pollinator habitat, and the availability and quality of water at local sources. The following data is derived from additional modeling work carried out in the framework of this evaluation (see also Sub-Appendix 3B).

Expanded pollinator habitat

Pollination is an ecosystem support service; supporting services perform functions necessary for ecosystems to continue providing more direct services, such as food supply. Pollinators play a critical role in the reproduction of many flowering, and even non-flowering, plants in the Cerrado biome.[19] In particular, the biome hosts a wide variety of bees that provide both pollination services and honey and that face several threats, including from vegetation-clearing and pollution.

In addition to supporting livestock and conserving forest habitat in a biodiverse region, restoring pasture provides increased pollinator habitat and abundance benefiting surrounding agriculture.[20] Coffee and soy are two leading pollinator-dependent commodity crops grown in the Cerrado biome, covering 243,053 hectares and 7,853,068 hectares respectively.

The Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) model calculates the effects of land cover conversion on pollinator abundance (in terms of changes in an index value), as well as potential changes in crop yield.[21] We used the InVEST pollination model to map and qualitatively describe changes in pollinator abundance on soybean and coffee fields resulting from potential nearby pasture restoration. Specifically, we compare relative pollinator abundance before ("baseline") and after ("restoration") to ILM pastureland restoration activities.

The model demonstrates that pastureland restoration increases pollinator abundance and that these benefits improve agricultural productivity in neighboring crop fields. The model produces a map of relative pollinator abundance between the two scenarios based on available nesting and foraging resources within the maximum flight distance of pollinator species. In the area studied, the area of soy and coffee within the European honeybee's maximum flight distance from pasture was 234,275 hectares and 5,921,802 hectares, respectively. Based on the biome's landscape, 96 percent of coffee crops and 75 percent of soy crops are within pollinator flying distance of pastureland. Thus, restoration of pastureland is likely to support crop pollination. If all pastureland were restored, pollinators would have access to 75 percent of the soy crops and nearly all of the coffee crops in the biome. This may improve productivity of these crops and/or reduce the need for farmers to provide replacement pollination services for their crops. (See sections further below on productivity and economic benefits.)

Expanded access to water resources

According to the BIP, sound environmental services practices also protected ecosystem services such as water and soil conservation.[22] Notably, the restoration of pastures also made them more resilient to drought and frost according to interviewees. In some instances, farmers have become water producers through the protection and recovery of springs, substantially increasing resilience to drought.

A number of DGM projects protected water sources. Project 004 protected four springs from trampling by cattle, with observed increasing humidity in the soil. However, full water security has not yet been achieved in the short time period of project implementation.[23] Another DGM project (project 016) recovered and protected 20 springs (the equivalent of approximately 20 hectares) providing potable water for 26 families. The community previously faced serious risk of displacement and potential "ethnicity extinction" without access to water. According to one stakeholder, "without water we would not live."[24]

Carbon sequestration

Carbon sequestration was the topline impact sought by the ABC project, with an estimated 6.6 million tCO_2e sequestered by the project treatment versus the control group. EMBRAPA estimated that the project will sequester 7.4 million tCO_2e over the next 10 years.[25] At US$40 per tCO_2e,[26] the mitigation benefits would be equivalent to $296 million. Considering the World Bank Group's $10.6 million investment in the ABC Project, such estimates implied a benefit–cost ratio of $27.90/$tCO_2e$ over a 10-year time span. The ex-ante economic internal rate of return (EIRR) calculated at appraisal was 17 percent. Ex-post, including shadow prices and the value of carbon sequestration (with carbon prices at $40/$tCO_2e$ sequestered) the estimated EIRR was 39.19 percent.

Economic impacts

Agricultural productivity

Improved land management practices influenced farm productivity for ABC project participants. There is existing evidence, within and outside of the immediate ABC projects, that land use changes have positive effects on farm productivity, notably the recovery of degraded pastures for milk and meat productivity of cattle.[27] SENAR estimated that cattle productivity increased significantly, with cattle stocking rates growing from 0.7 to 2.5 animals per hectare, and cattle weight gain increasing from 400 to 900 grams per day, also speeding time to slaughter from 36 to 19 months.[28] These productivity benefits were confirmed by interviewees, who also noted that there was broader improvement in farm management as a result of the training and technical assistance provided. This increased land use efficiency is expected to reduce incentives for deforestation and expansion of the agricultural frontier, thus further contributing to avoidance of future GHG emissions.[29]

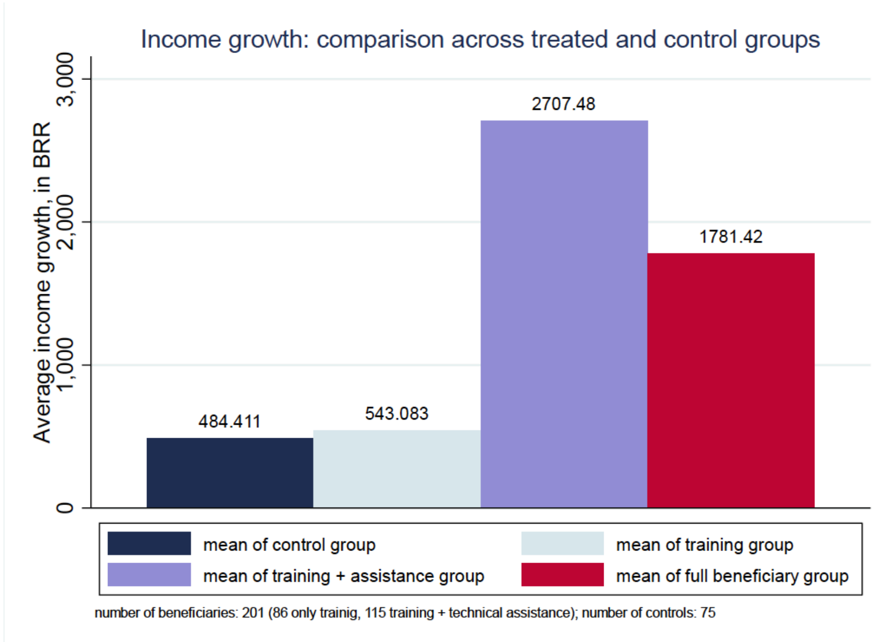
Improved productivity was also seen in a number of DGM projects. One of the main mechanisms promoted by the DGM projects was supporting the installation of so-called production units (communal agricultural production elements) within the agricultural matrix balancing conservation and production in Indigenous communities (e.g., DGM project 108, 016, 250). As a result, the volume, value-added, quality, and recognition of the products increased.[30] With water supply ensured and risks of fire reduced in the production unit, one of the selected projects for review reported more consistent trade in local markets.

Focusing on the commercialization of native products (e.g., Babassu nut food projects), the Work Cooperative for the Provision of Services for the Sustainable Rural Development of Family Agriculture (COOTAP) supported the construction of a Babassu production unit, substantially increasing production and even access to new markets. Through a second Babassu project, both the quality and labeling of products also improved, reportedly resulting in greater sales (though no sales data was systematically collected by the DGM project and is therefore not available). Babassu products are now even included in the state school lunch. Awareness and consumption of Babassu products was further enhanced through the preparation and distribution of a recipe book.[31]

Increased income

The ABC project increased farmer incomes. According to the ABC Project Completion Report (PCR), the project boosted beneficiary farmers' financial conditions, as beneficiary producers had an average income growth 3.7 times higher than producers in the control group, with the CAP group being 1.1 times higher and the CAP+ATEG group being 5.6 times higher (see Figure 3).

Figure 3. Project Impact on Farmers' Monthly Agricultural Income



***Source**: Author's elaboration, using data collected for SENAR's Impact Evaluation*

Several interviewees confirmed the influence of the ABC project on improving production quality, positive financial returns, and the contribution of the project to the property management process.[32] "Incomes increased, due to better pasture quality and/or agriculture/pasture integration, resulting in reduced costs associated with cattle feeding in the dry season."[33] Resulting savings also meant that greater resources were available for land protection (e.g., fencing) and tree-planting.[34] This qualitative evidence reinforced the project's assumption that not only can agricultural production and environmental conservation coexist, but they can in fact reinforce each other in a virtuous cycle.[35]

Similar development impacts on employment and income are expected from the ILM project. Like the ABC project, it aims to "increase employment and income for landholders (including land-reform settlers and traditional communities) and other partners in the business chain generated by farming activities, thereby contributing to poverty alleviation."[36] The project also aims to contribute to the employment of 150 people, a quarter being women, in agricultural services and restoration practices.

DGM income and livelihood benefits are more complex to measure. For the DGM project, livelihood benefits were assessed based on the number of projects generating these impacts, which was projected to reach 50. Based on information readily available, it was not possible to quantify and aggregate the income benefits of these interventions. Nevertheless, there is testimonial from both project staff and beneficiaries of resulting income increases. For example, in the Babassu projects, the participating women's income increased, as women gathering the nuts kept a percentage of the sales. "Sales during the COVID pandemic were essential for the economic sustainability of not only Quebradeiras de Coco Babaçu (CIMQCB) members, but also surrounding families in the Quilombola community."[37] Both monetary and non-monetary benefits are expected among about 3,000 forest users as well, due to livelihood diversification and sustainable forest/land use management systems. A study is underway to estimate these effects.

Social impacts

Gender-related benefits

Development impacts on gender roles were evident where they were actively pursued. At design, the overall BIP approach to gender issues was limited, with a focus mainly on gender assessment, related consultations, metrics, and compliance with World Bank and any national policies and safeguards.[38] However, compliance with World Bank and national policies and safeguards subsequently influenced the mainstreaming of gender into the individual projects.

By the end of the ABC project, 25–30 percent of the farms were led by women or had strong participation by women, with a positive influence notably on the speed of implementation, as well as concrete results achieved by the projects. This is in line with the estimated 20–30 percent female ownership of farms across Brazil.[39] The ABC project had 2,931 clients who adopted ABC technologies, 475 of whom were women, which was 81 percent of the original target for women participants.

Initially, the ABC project explicitly downplayed its gender-related objectives. The main focus of the ABC project was on maximizing ABC technology adoption, less on promoting gender equality of roles in farming communities, based on the Project Appraisal Document (PAD), as well as interviews with MAPA and SENAR. Likewise, there were initially no gender-specific targets in the results framework for female project participation, or specific gender-oriented interventions among its activities. After a critical mid-term external assessment, the ABC project did improve gender integration into its activities, notably communications and more equitable participation of women in training events. SENAR improved its communication strategy to attract more women at training events through advertisements specifically targeted at women; by hiring female instructors, field technicians, and supervisors; and by featuring more women in training videos. Ultimately, 2,300 female producers received training and/or technical assistance (20.2 percent of the total) by the ABC project. The ABC project also trained 1,781 female field technicians (22 percent of the total).[40]

The ILM project substantially improved gender mainstreaming in its design. The landscape management project met all formal requirements for gender assessment, measurement, and action.[41] It was more ambitious than its predecessor in both gender targets, as well as gender-targeted activities, such as, gender assessments, the facilitation of women's participation in formal and informal decision-making structures and governance processes related to the equitable provision of inputs for restoration, and training for capacity strengthening to ensure effective participation in activities to be implemented through the cash-for-work scheme.[42] According to the NSC progress evaluation, 30 percent of those adopting landscape restoration practices were women.[43]

Women had an influence on decision-making and more downstream marketing activities. Overall, while land ownership remained low among women in the ABC project (see Table 4), according to the ABC project impact evaluation, on around 35 percent of the target farms, women have an influence in the decision-making process and consequently the adoption of the low-carbon technologies. A difference seems therefore to remain between the estimate of 20–30 percent woman-managed farms nationally (see above), and actual land ownership. Also, as the number of farms declined, the percentage of woman-managed farms increased and was strongly correlated with the level of education.[44]

Table 4. Percentage of Woman-Led Farms in ILM-Participating States

States	% Woman-Owned Farms
Goiás	22.4
Tocantins	22.4
Mato Grosso do Sul	18.4
Maranhão	12.2
Minas Gerais	12.2
Piauí	6.1
Distrito Federal	4.1
Bahia	2

More indirect influence of women in decision making was confirmed by a number of interviews. According to one, "women's participation (in farming) was instrumental in several cases, not only due to direct participation, but also supporting activities and/or opening doors." Women appeared to have a particular role in the marketing of products and financial administration.[45] The increased land productivity stemming from the (husband's) adoption of ABC technologies also seemed to have a positive spillover on the productivity of women's downstream processing activities as well, contributing to an increase in their profitability. A perception analysis with 313 producers carried out in the PCR also highlighted, on average, a slightly higher willingness to adopt ABC technologies among women farmers than among men.[46]

The DGM projects were particularly successful in attaining their gender empowerment objectives, due to specific interventions and targets for women, including in IPTC representation on governance structures. Well over half of the final DGM project beneficiaries were women, far exceeding the gender target of 30 percent.[47] All of the selected projects reviewed for this case study also demonstrated very positive gender-related outcomes. For example, women and youth became engaged and empowered in the installed production units in two of the selected projects (project 108, 250). Women's and youth empowerment were also enhanced through their active participation in the community brigades that were trained to protect water springs and reduce the risk of fires, with around 140 participants, with almost 30 percent being women in another selected project (DGM project 004). Some of the DGM projects (e.g., project 004) also resulted in formalization of land tenure, and potential benefits of registering in the Rural Environmental Registry (CAR) for female farmers.

The DGM-funded Babassu projects supported the Interstate Movement for the Quebradeiras de Coco Babassu (MIQCB), which calls for the open access and communal use of Babassu palm trees and was started by a small group of women in 1991. The DGM support had three main results: 1) empowerment of women, 2) economic impacts, and 3) the passage of legislation to protect the Babassu forests as an income source. The DGM support had a particular empowerment effect on the women involved through the MIQCB. The Babassu nut breakers were termed "warriors" because they had the courage "to fight and say things," according to one of the nut breakers. One of the warriors' struggles was to access the Babassu trees and nuts on cattle pasture, which had resulted in substantial violence, even the murder of some of the women involved. The movement advocated for their right to access the Babassu forests, ultimately, resulting in the "Free Babassu Law," protecting the Babassu forests and giving free access to the Babassu coconut for landless coconut gatherers at the regional level.[48]

Drivers and Barriers that Affect Results

Increased understanding of the need for conservation and sustainable practices

Improved perceptions of conservation and environmental sustainability

The ABC project improved the overall perception around the importance of conservation and environmental sustainability. Supported farmers are now more open to the use of sustainable production practices such as protection of springs and water reservoirs, conservation of permanent protection areas and environmental protection, burning control, and use of plant residues for soil cover.[49] There was also growing understanding of the returns from sustainable farming practices. More broadly, some of the field technicians trained by the project are now teaching environmental education and the principles of ABC technologies in schools in some project sites. The DGM project also promoted increased awareness, and it demonstrated how community organization could greatly expand the reach of sustainable agricultural efforts. The Babassu projects were critical for the harmonization between scientific and popular knowledge.

Engagement of farmers

The main challenge in reaching DIs was the identification and engagement of interested farmers and related project design issues, notably in relation to the experimental design of the ABC project. According to the BIP, there was a risk of non-adoption of recommended technologies.[50] One of the main barriers to the ABC and ILM projects was the deep hesitation of some farmers to adopt new practices, especially ones that were offered free of charge,[51] which were viewed with suspicion.[52] In particular, cattle ranchers were found to be conservative, with limited uptake of new ideas and technologies.

The experimental design of the ABC project disincentivized participation, due to the risk of being assigned in the control group.[53] In the ILM project, despite efforts at awareness raising and communications to attract farmers to the project, five watersheds had to be replaced because a sufficient number of farm properties could not be identified in the original design. The sought average size of the farm also had to be reduced from 300 hectares to as small as 30–50 hectares.[54]

The degree of retention of training content required to implement improved practices was originally a concern,[55] but it was monitored and shown to be a limited risk to the ABC project. Based on project data collection, retention of ABC project training content was particularly high six months after coursework completion (76 percent). The project also introduced distance learning modules to sustain training benefits after project end.

IPTC empowerment and farmer organization

Of the selected projects, the DGM projects had the most explicit objectives and clearest results in the empowerment and organization of Indigenous people and traditional communities (IPTCs). For the DGM project, the main emphasis was on strengthening the representative organizations of IPTCs, their relationships, and influence in REDD+/climate change decision-making bodies at the local, national, and global levels.[56] This was rooted in a highly participatory empowerment strategy. The DGM projects were explicitly expected to increase IPTCs' presence and voice through IPTC representation in governance structures, on policies and programs related to forest adaptation, REDD+, and climate change adaptation.[57] Based on the selected projects, a number of them also either created or strengthened IPTC representative bodies (e.g., CITAP, CIMQCB) or empowered communities to cooperate more organically (e.g., project 108, 016, 004). Overall, 27 organizations were supported by 2020 through the DGM funding.[58]

ABC empowerment and farmer organization

The ABC project contributed to farmer organization and empowerment. Access to inputs may "pave the way for higher associative activity and better social capital in project areas and beyond."[59] These broader benefits on farmer empowerment and coordination were confirmed by interviews. For example, coordination among farmers from different regions increased, notably on marketing, with resulting increases in prices obtained. [60]

Institutional capacity and learning

Institutional structures and processes were important mechanisms for achieving results, but occasionally posed barriers to change. As already noted, the FIP projects were well integrated into the climate change commitments of the Brazilian government, as well as the policy and regulatory framework guiding their implementation. Notably, the FIP's ABC project was a main piloting and implementation mechanism of the Government's overall ABC Plan. The successful collaboration among the three Ministries (Ministry of Environment, MMA; Ministry of Agriculture, Livestock and Food Supply, MAPA; and Ministry of Science, Technology, and Innovation, MCTI) allowed the development of a strategic approach capable to foster synergies not only among the Brazil Investment Plan and its projects, but also with ongoing Cerrado government plans and policies already in implementation at federal, state, and municipal levels.[61]

Institutional/project management capacity

Institutional capacity, including project management capacity, improved through the implementation of FIP interventions**.** While lack of experience resulted in initial delays in the implementation of the ABC project, project management capacity improved substantially over time, notably at SENAR. The ABC project was the first activity financed by international resources that SENAR implemented. The agency had to improve its approach to project management, monitoring and evaluation (M&E), fiduciary aspects, and safeguards. In addition, SENAR invested its own resources to further train its technical team on topics such as management, acquisitions, and impact assessment, and in certain cases SENAR's staff themselves invested to achieve even deeper training. SENAR was also able to innovate on its offer of services, developing an entirely new technical assistance curriculum, as well as distance-learning modules to continue offering ABC training to rural producers after project closure.[62] The confidence in the project management arrangements was also demonstrated by the successor ILM project, which is also implemented in coordination between MAPA and SENAR.

The DGM project also supported the capacity of the Centro de Agricultura Alternativa do Norte de Minas, its implementing agency, governance structures, and IPTC representative groups. In the DGM project, 12 members of the National Steering Committee and 22 subproject representatives were supported in conservation and other REDD+ related processes at the regional, national, and global level.[63] Institutional capacity building of IPTC organizations and networks was also essential "to enhance their knowledge, skills and participation in decision-making processes related to forest/land use management and climate change adaptation."[64] In the case of the DGM subprojects selected for deep review for this case study, notably the DGM support to the Babassu Coco Women's Interstate Cooperative, the Cooperative substantially enhanced its capacity, including professionalization of staff and roles, and its ability to participate in future calls for proposals.[65]

Technical assistance

Substantial institutional learning on provision of technical assistance resulted from FIP investments in Brazil. With the experimental design of the pilot ABC project, important learning was captured on the value of technical assistance beyond training. Moreover, SENAR has continued technical assistance, despite the end of the project. The DGM project also demonstrated the importance of a contextually relevant package of technical assistance and training when working with organizations representing IPTCs.[66]

Interagency coordination and project management

While the BIP emphasized the interdependence of the portfolio and the need for coordination and partnerships to achieve shared objectives, interagency coordination remained a weakness. The ABC project in particular did not fully benefit from the potential institutional synergies between different agencies. While different agencies had potential added value in different areas of the project, such as guiding the overall direction, scientific advisory, and execution of the project, these were not fully embraced. This finding came through in both document review and during interviews. "The project did not establish a specific definition of attributions, internal guidelines, and resource flows between these institutions. This meant that implementation missed the opportunity to fully exploit the synergies that would have arisen from greater involvement of MAPA and EMBRAPA."[67] One interviewee summarized the situation by noting that "the level of involvement and buy-in from the other partner, EMBRAPA, remained below potential throughout implementation."[68]

One of the critical lessons learned from the ABC project was that more integrated, spatial management was needed, beyond individual farm units. The successor ILM project had a greater focus on the crucial elements of integrated landscape management, through its focus on selected watersheds, such as spatial planning and monitoring. One interviewee summarized the ILM's greater success in this area as follows: "The integrated landscape approach provided the solid technical basis needed to make the trade-offs between conservation and development explicit, as well as to foster platforms for negotiation about these trade-offs."

CIF and MDB Contributions to DIs

While the FIP grant to the ABC project was small in comparison with the overall, national investment of US$1.5 billion (this was not considered co-funding) in the ABC plan 2010–2020, it was nevertheless important, notably in incentivizing and measuring the achievement of the sought DIs. The experimental design of the project was only possible with the external grant funding. It allowed for the rigorous assessment of the attributable effect of the grant on the impacts of training and TA on farmer productivity and income, providing valuable lessons well beyond the individual intervention. The experimental design also directed focus on DIs beyond the immediate outputs, where usually measurement efforts end, in areas such as land restoration. Finally, both the complex project design, as well as its daily management, built substantial expertise and project management capabilities, notably at SENAR, which was confirmed through interviews. It was too early to tell the specific contribution of the investment into the ILM project, but it did provide a more integrated, spatial approach to landscape management in the Cerrado.

Future Opportunities: Lessons for CIF and Other Climate Funders

FIP and similar future investments can benefit biodiversity conservation

Biodiversity was identified as one of the main co-benefits of the Integrated Landscape Management project.[69] Promoting restoration and protection of critical habitats within private landholdings was one of its main pillars, including re-establishment of biological and hydrological flows; reconnection of fragmented habitats; and restoration of multiple ecological processes. As discussed above, improved agricultural and land management practices will also improve environmental services in the Cerrado, including expansion of pollinator habitat, and the availability and quality of water at local sources. The successor ILM project is expected to further expand and generate territorial and integrated landscape approaches, together with the relevant partner agencies. An interviewee said it "seeks to maximize biodiversity connectivity benefits as well as water and soil benefits beyond the farm limits."[70]

The understanding and replication of the low carbon agricultural practices was critical for its broader uptake beyond the projects and impact at scale. The understanding and replication of the technologies by neighboring farmers and even other regions of the country were an explicit objective of the ABC project logic. Likewise, the ILM project was expected to provoke replication effects in other watersheds in the country.

The immediate replication logic followed from the proven financial returns from the adoption of ABC technologies, resulting in increasing uptake by beneficiary farmers, even beyond project resources with their own funding. The proven and demonstrated financial profitability of the ABC technologies, together with a high degree of training and technical assistance content retention, indicate a high likelihood of continued adoption of low-carbon agriculture post-project. According to interviews, farmers have continued the use of ABC technologies after the end of the project, at times even paying for SENAR technical assistance at their own cost.[71]

Likewise, the demonstrated viability of the ABC technologies and growing environmental awareness among Cerrado producers had an influence beyond the project beneficiaries, due to the demonstration effect of the economic viability and desirability of ABC technologies on beneficiary farms. Around 30 percent of interviewed beneficiaries indicated that their adoption of ABC technologies is inspiring neighboring producers to reorient their production toward more sustainable agricultural practices.[72] The consolidation of a low-emission economy in the agricultural sector will improve the efficient use of natural resources and encourage producers and rural communities to play a positive role in deforestation reduction.

The lessons learned, training, and dissemination materials and tools successfully deployed in the Cerrado will be used by MAPA and SENAR to promote broader access to the ABC Plan in all other regions of Brazil, contributing to expand the adoption of low carbon agriculture in Brazil.[73] The joint impact of the FIP portfolio as a whole was also greater than the sum of its parts at the biome level to maximize the sustainability and efficiency of land use and forest management. “For example, the environmental regularization of rural lands in the Rural Environmental Registry, enabled by the FIP-CAR project, will enable producers to access resources from the ABC Plan credit lines, and the quasi-real-time framework for deforestation monitoring built by the FIP-Systems project will help ensure that producers do not go back to expanding the agricultural frontier.”[74]

Even the substantially smaller DGM projects recorded evidence of a “multiplication effect” from improved land management and environmental practices across different communities, with the potential of covering around 170,000 hectares of Cerrado. For project 004, this was particularly the case for fire monitoring practices.[75]

Leveraging funds for cattle farmers and crop growers

Ability to leverage funds was less of a constraint to expansion for cattle farmers than crop growers. Even though the leveraging of additional finance for the private farmers was one of the sought results and indicators of the ABC project, access to the ABC Plan credit facility (i.e., loans) proved less relevant than expected. At ABC project closure, only 1 percent of trained producers had requested credit to finance the adoption of ABC technologies, but project beneficiaries who received technical assistance invested their own resources in pasture rehabilitation and improved farm management, investing US$7.20 of their own funds to adopt the low-carbon technologies for every dollar invested in technical assistance by the project.[76] Cattle ranchers are generally more disconnected from the financial system than crop growers, as they use cattle as their preferred saving/investment device. Farmers’ willingness to self-finance also demonstrated the value of technical assistance and training, especially for medium-sized operators. Incentive programs may nevertheless be necessary for relatively poorer producers.

The global COVID-19 pandemic had the greatest, unforeseen impact on the selected FIP interventions, notably the DGM projects, with a demonstrated need to adjust project designs to meet unforeseen contextual challenges. According to the NSC process evaluation, the pandemic fundamentally altered the activities of the DGM project, shifting them toward both the prevention of infection, as well as mental health.[77] Though unplanned, DGM project activities proved critical for helping keep beneficiaries and their families safe during the pandemic.[78]

Sub-Appendix 3A. Legal and Policy Context: History of Brazil’s Climate Commitments and the ABC Plan

Brazil’s National Plan on Climate Change, launched in 2008, and the National Policy on Climate Change Law (NPCC), enacted in 2009, set national voluntary commitments to reduce GHG emissions by 50 percent by 2020. The set of mitigation actions stipulated by the NPCC to achieve this goal included reducing the rates of deforestation by biome and disseminating sustainable technologies in the agricultural sector. Decree No. 7,390, December 2010, which regulated the NPCC, established specific targets for reducing GHG emissions, also including 40 percent reduction of deforestation in the Cerrado compared to the 1999-2008 average, recovery of 15 million ha of degraded pastures, expansion of crop, livestock, and forestry integrated systems in 4 million ha, and expansion of no-tillage farming systems in 8 million ha.

In 2010, in the context of the NPCC, the Ministry of Agriculture, Livestock and Food Supply (MAPA) developed the "Sector Plan for Mitigation and Adaptation to Climate Change for the Consolidation of a Low Carbon Emissions Agriculture Economy," also known as the ABC Plan, to implement these commitments. Its overall objective was to promote the reduction of GHG emissions and the increase of carbon sequestration in agriculture by improving efficiency in the use of natural resources, increasing the profitability and resilience of production systems, and enabling adaptation of the agricultural sector to climate change. The plan aimed to introduce climate-smart technologies on 30 million hectares between 2010 and 2020, and thus reduce emissions by 158 million tons of CO_2e. The main ABC technologies were:

- Integrated systems (crop-livestock-forestry, mixed farming, livestock-forestry, and other agroforestry systems) and no-tillage systems;
- Biological nitrogen fixation (BNF);
- Planted forest;
- Restoration of degraded pastures; and
- Animal waste management.

The main financial instrument of the ABC Plan was the provision of a subsidized credit line for farmers (ABC Credit Line), to support the upfront costs of converting traditional agricultural practices. Between 2010 and March 2020, the credit line entailed a total investment of around R$19.7 billion (around US$6.7 billion using monthly average exchange rates over the period), making it one of the largest climate-smart agriculture programs in the world.[79]

The Brazilian Forest Code (Law 12.651 of 2012) requires that all private rural landholdings maintain a percentage of native vegetation as Legal Reserves (RLs), and that Areas of Permanent Preservation (APPs), such as riparian forests along watercourses, steep slopes, and mountaintops, also be maintained and preserved by landholders. The Forest Code also obliges landholders to register their landholdings in the Rural Environmental Registry (CAR). This registry contains details on the total area of individual farms, the areas earmarked for alternative land use, APPs, and RLs.[80] Up to January 2020, 1,041,673 rural properties in the Cerrado, representing 160,966,999 hectares, have been registered in the CAR. The following environmental information have been included in the Cerrado registry:[81]

- 56,514,994 hectares of native forest;
- 7,404,372 hectares of APPs;
    - 4,899,649 hectares of native forest within APPs

- 35,134,896 hectares of RLs;
    - 27,362,491 hectares of native forest within RLs; and
- 388,422 water springs.

Brazil´s public forest lands under protection, including the Indigenous Lands, account for around 200 million ha, with very low rates of deforestation or degradation. Around 8 percent of the Cerrado biome consists of Protected Areas. Of this total, 2.85 percent are for strict protection and 5.36 percent are for sustainable use. Indigenous lands occupy about 4.4 percent of the biome.[82]

In 2015, Brazil submitted its Nationally Determined Contribution (NDC) to the United Nations Framework Convention on Climate Change (UNFCCC). Brazil committed to reducing GHG emissions by 37 percent below 2005 levels by 2025 and, as a subsequent indicative contribution, to reducing GHGs by 43 percent below 2005 levels by 2030. Brazil's climate change commitments were most recently revised at COP 26, where Brazil reiterated the reductions of 37 percent in 2025 and of 43 percent in 2030, always with reference to 2005 and announced its new commitments to achieve climate neutrality (long-term goal) by 2050.[83] As part of the NDC implementation and to further reduce the GHG emissions from agricultural practices, MAPA announced, on April 20, 2021, the release of a strategy for the Brazilian Plan for Adaptation and Low Carbon Emission in Agriculture for 2020–2030 (ABC+)[84], which is a new iteration of the ABC Plan.

Sub-Appendix 3B. Methodology for Pollinator Modeling

The Integrated Landscape Management (ILM) Project in the Cerrado biome aims to improve forest management and land-use planning in the Cerrado biome by promoting low carbon agricultural practices.[85] The Cerrado is one of the world's largest biodiversity hotspots, providing habitat to a large number and diversity of species, many of which are endemic to the region. The natural resources and species of the region provide ecosystem services that contribute to the health, wealth, and well-being of people in the region providing essential resources and services to support rural livelihoods. These include providing drinking water supply; hydropower generation; food and agricultural production for food security; production of raw materials for medicine, fuel, and building materials; and tourism and recreational opportunities. The primary threat to biodiversity and ecosystem services in the Cerrado biome is the clearing of land for pastures and monoculture agriculture. Accordingly, the Critical Ecosystem Partnership Fund (CEPF) has identified promoting the adoption of best practices in agriculture as the highest priority strategy for conservation.[86] The ILM Project targets sustainable agriculture practices for mitigating carbon; however, these practices also provide important co-benefits (i.e., benefits beyond the carbon mitigation objectives). This case study focuses on the following benefits of the ILM Project:

- **Protecting biodiversity:** We provide context on the global significance of the Cerrado biome as a biodiversity hotspot and the importance of minimizing and mitigating agricultural expansion to protect vulnerable species and habitats.
- **Providing ecosystem services:** The biome supports human well-being through provisioning services (e.g., food, fuel, raw materials); supporting services (e.g., pollination); regulating services (e.g., water cycles, carbon storage and sequestration); and cultural services (indigenous and rural livelihoods, tourism and recreation). We provide an overview of these services and the threats introduced by agricultural expansion.
- **Pollination services:** Given the importance of agriculture and food production both to local populations and to the economic vitality of the region, we focus in particular on the benefits of native pollinator populations, identifying how the ILM Project promotes pollinator production and contributes to productive agriculture.

Protecting biodiversity

The Cerrado biome is home to a variety of habitat types and is the most diverse tropical savanna in the world; and, except for a few tropical forest regions, it has the richest vascular plant flora on the planet.[87]

The International Union for the Conservation of Nature (IUCN) "Red List" for Brazil identifies over 1,500 terrestrial and freshwater species classified as critically endangered, endangered, vulnerable, or near threatened, with 320 of these species located in the Cerrado. The biome also contains 761 key biodiversity areas, geographic areas that the IUCN has identified as contributing significantly to the global persistence of biodiversity. Figure 1 illustrates species richness (number of species) specifically of species of concern, highlighting the significance of the Cerrado region both within South America and globally. Table 1 summarizes the types of threatened and endangered species present in the biome based on IUCN red list data. Table 2 describes the level of endemism of Cerrado species. Endemic species are native and restricted to a given geographic area; ecologists generally target regions with high levels of endemism, like the Cerrado, as priority areas for conservation in order to safeguard biodiversity. That is, regions with high levels of endemism provide habitat for species with relatively greater extinction risks.

Figure 1. IUCN Red List species Richness of Critically Endangered, Endangered or Vulnerable Species in the Cerrado Biome 2022. The IUCN Red List of Threatened Species. Version 2021-3.

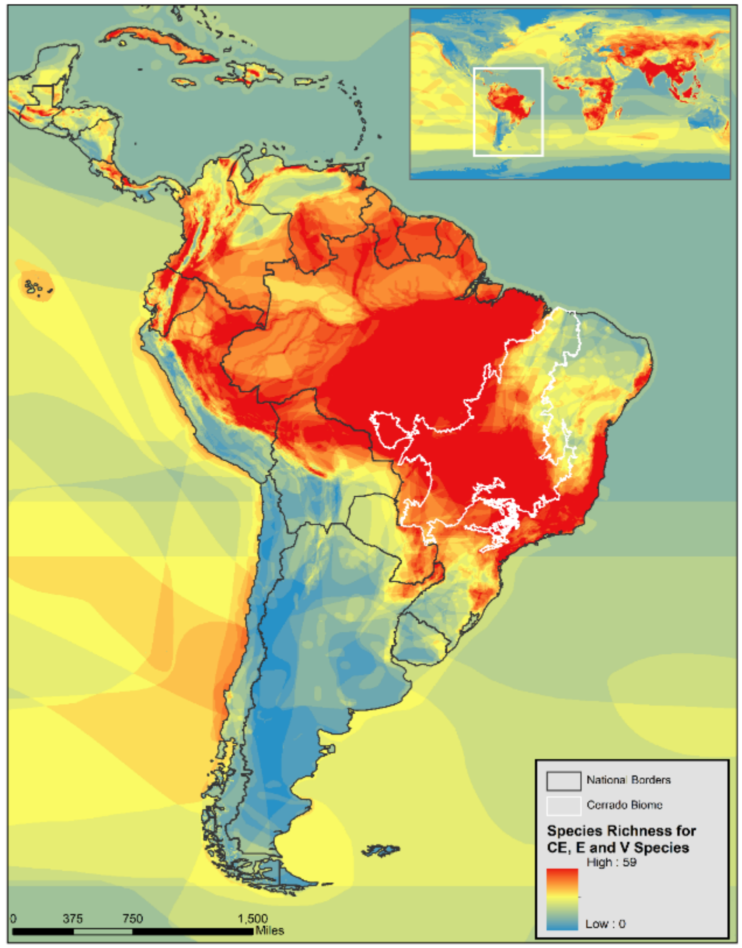


Table 1. Number of Species in Cerrado Biome Classified as Critically Endangered, Endangered, Vulnerable, or Near Threatened by the IUCN

Classification	Critically Endangered	Endangered	Vulnerable	Near Threatened	Total
Animals	**21**	**51**	**91**	**78**	**241**
Aquatic Animals	15	23	29	18	85
Birds	3	14	35	39	91
Mammals	0	9	16	17	42
Reptiles	2	3	8	2	15
Arachnids, Insects and Snails	1	2	3	2	8
Plants	**4**	**29**	**23**	**23**	**79**
Total	**25**	**80**	**114**	**101**	**320**
Source: IUCN 2022. The IUCN Red List of Threatened Species. Version 2021-3.					

Table 2. Diversity and Endemism of Plant and Vertebrate Species in the Cerrado Biome

Biological Group	Number of Species	Number of Endemic Species	% Endemism
Plants	12,070	4,208	34.9%
Vertebrates	2,373	433	18.2%
Fish	800	200	25.0%
Amphibians	204	72	35.3%
Squamata reptiles	262	99	37.8%
Birds	856	30	3.5%
Mammals	251	32	12.7%
Subtotal	**14,443**	**4,641**	**32.1%**
Invertebrates	*Total Invertebrates Unknown*		
Bees	820	417	50.9%
Total	**15,263**	**5,058**	**33.1%**
Source: Tables 3.1 and 3.2 of the 2017 CEPF Cerrado Biodiversity Hotspot Ecosystem Profile			

As the agriculture sector in Brazil has grown over the past 50 years, nearly half the biome has been deforested (Beuchle et al. 2015). The greatest threat to the species and habitats of the Cerrado biome is agricultural expansion, which includes deforestation for establishing pastureland and cropland. As shown in Table 3, the IUCN identifies that agriculture and ranching activities are a key threat to approximately 64 percent (67 species) of the 105 critically endangered and endangered species occurring within the biome, including the Brazilian merganser (*Mergus octosetaceus*) and the jaguar (*Panthera onca*). A primary focus of biodiversity protection in the biome is on minimizing and mitigating agricultural expansion to reduce habitat fragmentation and degradation. Through projects such as ILM, farmers and ranchers can learn to better manage their current pastures and thus decrease their need to expand into new areas, reducing the impact of agriculture and ranching on habitats and biodiversity.

Table 3. Number of Critically Endangered and Endangered Species for which Agriculture and Ranching Are Described as Primary Threats

Classification	Livestock Farming & Ranching	Non-Timber Crops	Logging/ Wood Harvesting	Agricultural & Forestry Effluents
Animals	**24**	**30**	**11**	**13**
Aquatic Animals	4	4	3	6
Birds	14	17	3	4
Mammals	5	5	4	2
Reptiles	1	2	0	0
Arachnids, Insects and Snails	0	2	1	1
Plants	**23**	**20**	**15**	**0**
Total	**47**	**50**	**26**	**13**

Notes: There are a total of 105 species identified by the IUCN as critically endangered or endangered within the Cerrado biome. Individual species may list more than one of these categories as primary threats; thus, the columns do not sum to a total number of species. The total number of species with at least one of the listed threats is 67 and the total number of species with either livestock farming & ranching or non-timber crops as a threat is 58.

Providing ecosystem services

The Cerrado biome experiences both direct and indirect threats through agricultural expansion, cattle-raising, erosion, invasive species, and so on. The biome experiences deforestation at an annual rate of approximately 6,000 km^2, a higher deforestation rate than is experienced by the Amazon Rainforest. It is estimated that in the past 50 years, it has lost around 50 percent of its native plant cover to agricultural expansion. The primary agricultural products responsible for deforestation and land conversion are soybeans, sugarcane, corn, cotton, and coffee. Not only do these agricultural products directly displace native vegetation, but they are also typically limited to one species of crop (i.e., a monoculture). The replacement of native species with monocultures lowers the region's biodiversity and, as a result, its resilience to natural threats such as droughts, invasive species, etc.[88]

In addition to the biodiversity, the Cerrado Biome provides a variety of important economic, cultural, and ecological services to Brazil. The biome is responsible for approximately 30 percent of Brazil's gross domestic product (GDP) and is culturally important to many Indigenous tribes. In addition to carbon storage and sequestration, following are ecosystem services provided by the biome that support human well-being. These services depend upon healthy, functioning habitats and biodiversity. Thus, land clearing for agricultural development and effluents from industrial agriculture represent key threats to these services as characterized below. Conversely, projects like the ILM that restore healthy, functioning habitats and biodiversity also support a range of important ecosystem services.

Food production

- Indigenous Peoples and traditional communities in the region rely on native fruits, nuts, fish, and honey for their own consumption. These communities also market these food products at local markets and for export. Some subsistence hunting also occurs on Indigenous lands. Agricultural expansion results in loss, fragmentation, and degradation of the habitats upon which these species depend.

- While large-scale industrial agriculture constitutes a threat to the biome's ecosystem services, agriculture and livestock production are an important economic sector in Brazil, accounting for more than 20 percent of the country's GDP. The Cerrado biome has the largest area of agricultural and pastureland in the country (44 percent).[89] For example, the Cerrado is the origin for commercial crop dispersion of pineapples, peanuts, beans, and manioc. Agriculture has historically been and will likely continue to be an important component of the region's economy. Consequently, encouraging sustainable intensification of pastureland and mainstreaming low-carbon agricultural practices are imperative to balancing the economic growth of the sector with the viability of the biome's species and ecosystems.

Water supply

- About 70 percent of all surface water in Brazil originates in the Cerrado. The biome is also home to the Guarini Aquifer, which is the second-largest underground reservoir in the world and supplies water to large parts of Brazil and neighboring countries. Clearing of surface vegetation for agriculture can accelerate runoff, cause sedimentation of surface waters, and interfere with water recharge, threatening the water supply. Water pollution from agricultural effluents (fertilizers, herbicides, insecticides, and fungicides) can also have negative impacts on biodiversity and human health.[90]

Hydropower

More than 200 million people in Brazil depend upon electricity generated by hydroelectric projects in the region, including the Itaipu hydroelectric plant on the Paraná River, one of the largest hydropower projects in the world. Clearing of native vegetation, especially from riparian areas, can cause sedimentation of reservoirs above hydroelectric power plants.

Fuel and building materials

Trees and other raw materials from the Cerrado provide fuel and building materials for rural populations. Some species are also used to build furniture for personal use or for local populations to sell.[91] This type of selective harvesting can be done sustainably; however, large-scale clearing and monoculture can limit these traditional uses of the ecosystem.

Recreation and tourism

The Cerrado landscapes include tourist attractions, such as thermal springs, waterfalls, caves, canyons, rivers and lakes for recreational fishing, and birdwatching hotspots. These visits depend upon natural features and recreationally valuable species and provide regional income from non-local and foreign tourists.

Medicinal products

Local communities collect and use medicinal plants sourced in the Cerrado biome. There are an estimated 220 species of flora with known medical uses in the biome.[92]

Pollination services

The mosaiced forest-agriculture patches in the Cerrado biome are known to support extremely rich habitat for pollinators.[93] Some Cerrado crops, such as soy and coffee, are classified as pollinator-dependent. However, agricultural expansion threatens pollinating fauna through the destruction of native food sources and habitats. This is of particular concern for the subset of bee species which rely upon the Malpighiaceae family of plants, whose flowers secrete oils rather than nectars, and the subset of bee species with a preference towards forested vegetation.[94]

Pollination is classified as a "supporting service" by the Millennium Ecosystem Assessment, meaning it is a function necessary for ecosystems to continue providing more direct services, including food supply and power generation. In this way, the effects of pollinator habitat loss and fragmentation on biodiversity and ecosystem services are amplified by the reduction in pollinator populations, such as bees, due to their critical role in the reproduction of many plants in the Cerrado biome.[95]

Insects, bats, and hummingbirds all provide pollination services, maintaining the biome's native plant communities that provide the basis for habitat and serve as the foundation of the food chain. In particular, the biome hosts a wide variety of bees that provide both pollination and honey and that are threatened by vegetation clearing and pollution, among other threats. The bees require nesting places, including hollow trees. Table 4 characterizes bee species by vegetation preference in the biome. A recent ecosystem profile of the Cerrado states that "keeping pollinator populations and their habitats throughout landscapes is essential to maintaining native biodiversity as well as crops."[96]

Table 4. Cerrado Bee Species Vegetation Preference by Family

	Vegetation Preference				
Bee Species Family	Cerrado (Savannah/Arid)	Riparian Forest	Forest	Undefined	Total[1]
Colletidae	5	27	11	1	44
Oxaeidae	2	0	0	2	4
Halictidae	27	55	24	79	185
Andrenidae	1	1	9	1	12
Megachilidae	22	31	47	60	160
Anthophoridae	49	103	88	112	352
Apidae	14	22	67	10	113
Number of Species	**120**	**239**	**246**	**265**	**870**

[1] Total sum of number of species is greater than 820 due to species with preferences with multiple vegetation types.
Source: Table 32 of Raw, 2007.

Pollinator-dependent crops in the Cerrado biome

A primary goal of the ILM Project is restoring degraded pasture to avoid continued deforestation from agricultural expansion. In addition to supporting livestock and conserving forest habitat in a biodiverse region, restoring pasture provides increased pollinator habitat and abundance benefiting surrounding agriculture. Coffee and soy are two leading pollinator-dependent commodity crops grown in the Cerrado Biome, covering 243,053 hectares and 7,853,068 hectares, respectively, across the states participating in the ILM project, including Goiás, Mato Grosso do Sul, Tocantins, Maranhão, Bahia, Piauí, Minas Gerais and the Distrito Federal (Table 5). Both coffee and soy are classified as "modestly" dependent on pollinators, experiencing a reduction in yield up to 40 percent without animal pollinators.[97] Due to the prominence of these two commodity crops within the Cerrado Biome, both benefit from pasture restoration and increased pollinator abundance through increased crop yield or reduced dependence on managed pollinators.

Table 5. Area of Pollinator Dependent Crops in the Cerrado Biome

Crop	State	Area (Hectares)	Total Area (Hectares)
COFFEE	Bahia	21,260	243,053
	Goiás	8,851	
	Minas Gerais	212,942	
SOYBEAN	Bahia	1,043,108	7,853,068
	Goiás	2,932,166	
	Maranhão	487,092	
	Mato Grosso do Sul	1,554,574	
	Minas Gerais	1,016,929	
	Piauí	471,070	
	Tocantins	348,129	

Source: MapBiomas Project, 2022

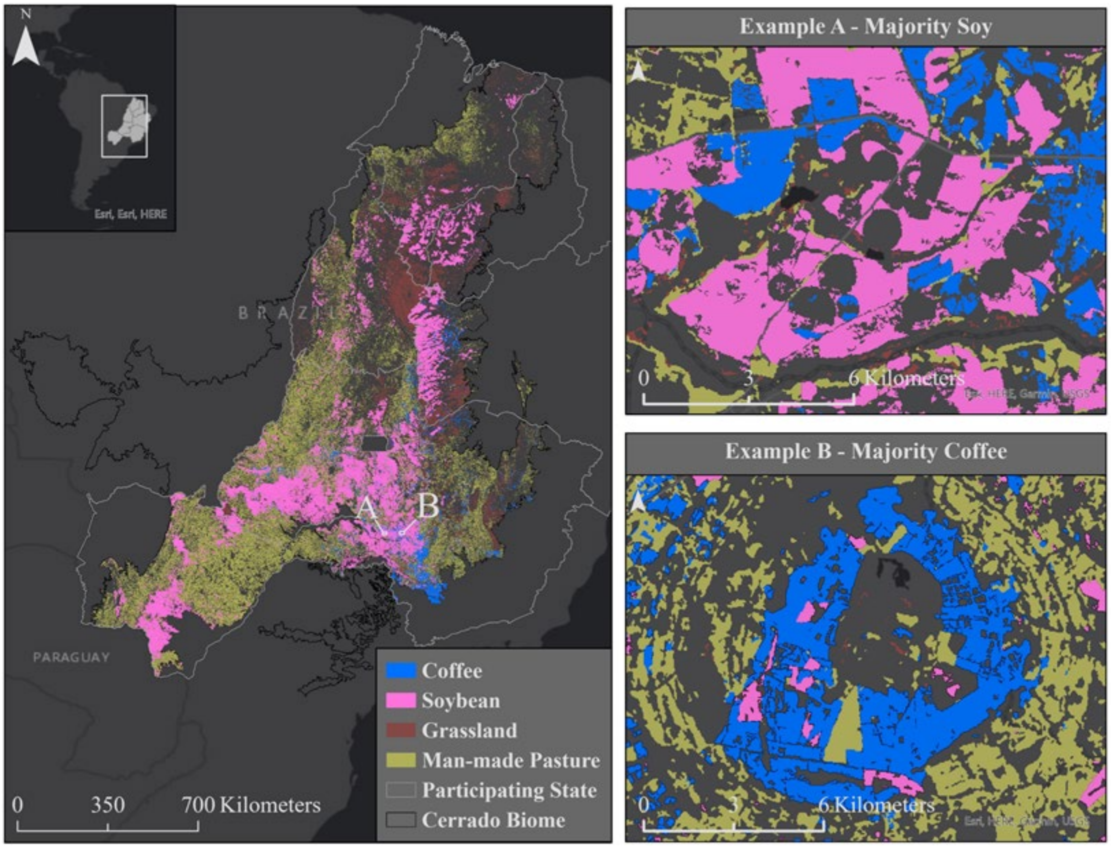
InVEST pollinator model

The Natural Capital Project maintains a variety of ecosystem service valuation models within a modeling platform referred to as the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) toolkit.[98] The InVEST Natural Capital Pollination model compares landscape management scenarios and assesses impacts to pollinator habitat and abundance by producing spatially explicit outputs. Inputs required to evaluate the effects of the land management and land cover scenarios on pollination services include the following:

- Land cover maps for each scenario;
- Identification of pollinator nesting and foraging resources in each land cover category;
- A list of pollinator species and associated habitat requirements; and
- The maximum travel distance of the pollinators in order to assess access to pollinator-dependent crops.

The model calculates the effects of land cover conversion on pollinator abundance (in terms of changes in an index value), as well as potential changes in crop yield.[99] Previously, the InVEST pollination model has been applied to the Cerrado Biome to examine how pollinator habitat and abundance supported by the Mata do Jambreiro, a protected mosaic forest-agriculture area in Minas Gerais, contributes to local agricultural yield and to identify municipalities where conservation of pollinator habitat should be prioritized (see Figure 2). As the InVEST model does not evaluate the monetary value of the service, the study included a separate monetary valuation of crop yield attributable to pollinators by identifying agricultural fields within the maximum flight distance of pollinators and multiplying the monetary yield of those fields by a crop's pollinator dependence.[100] Ultimately, the study found that the Mata do Jambriero contributes up to US$246,000 to agricultural production on croplands within 26 kilometers of the protected area.

Figure 2. Distribution of Pasture and Grassland in Participating States



Source: Mapbiomas Project, 2022; Instituto Brasileiro De Geografia E Estatística (Ibge), 2020; Global Forest Watch, 2019.

This case study relies on elements of the InVEST pollination model to map and qualitatively describe changes in pollinator abundance on soybean and coffee fields resulting from potential nearby pasture restoration. Specifically, we compare relative pollinator abundance before ("baseline") and after ("restoration") the ILM pastureland restoration activities. Our analysis employs the following general method:

1. We rely on the MapBiomas landcover map (2014) as the primary input for this model reflecting the baseline land cover before ILM Project restoration activities. The GIS map contains 34 land cover categories, including man-made pasture, grassland, soybean agriculture, and coffee agriculture (Exhibit 8).
2. We identify pollinator nesting and foraging resource availability for each land cover category that were assigned based on the parameters used by Hipólito et al. (2019).[101]
    a. For the baseline scenario, we assign the pollinator nesting and foraging parameters defined for "man-made pasture."
    b. For the restoration scenario, we assume the "man-made pasture" is restored to conditions similar to "natural grassland" and assign pollinator nesting and foraging

parameters accordingly. Based on Hipólito et al. (2019), restoration of degraded pasture to grassland conditions can double available nesting and foraging resources for pollinators.

We rely on information on *Apis mellifera* (European honeybee) as a proxy to characterize bee pollinators in the model because this species is the most common bee species identified in agricultural fields in the Cerrado region and is a key pollinator of both coffee and soybeans. Habitat requirements for the European honeybee are based on the parameters used in Hipólito et al. (2019). However, Brazil has over 1,600 native wild bee species. Therefore, this model does not fully account for the contribution of wild bees and likely underestimates the benefits of pasture restoration on pollinator abundance.[102]

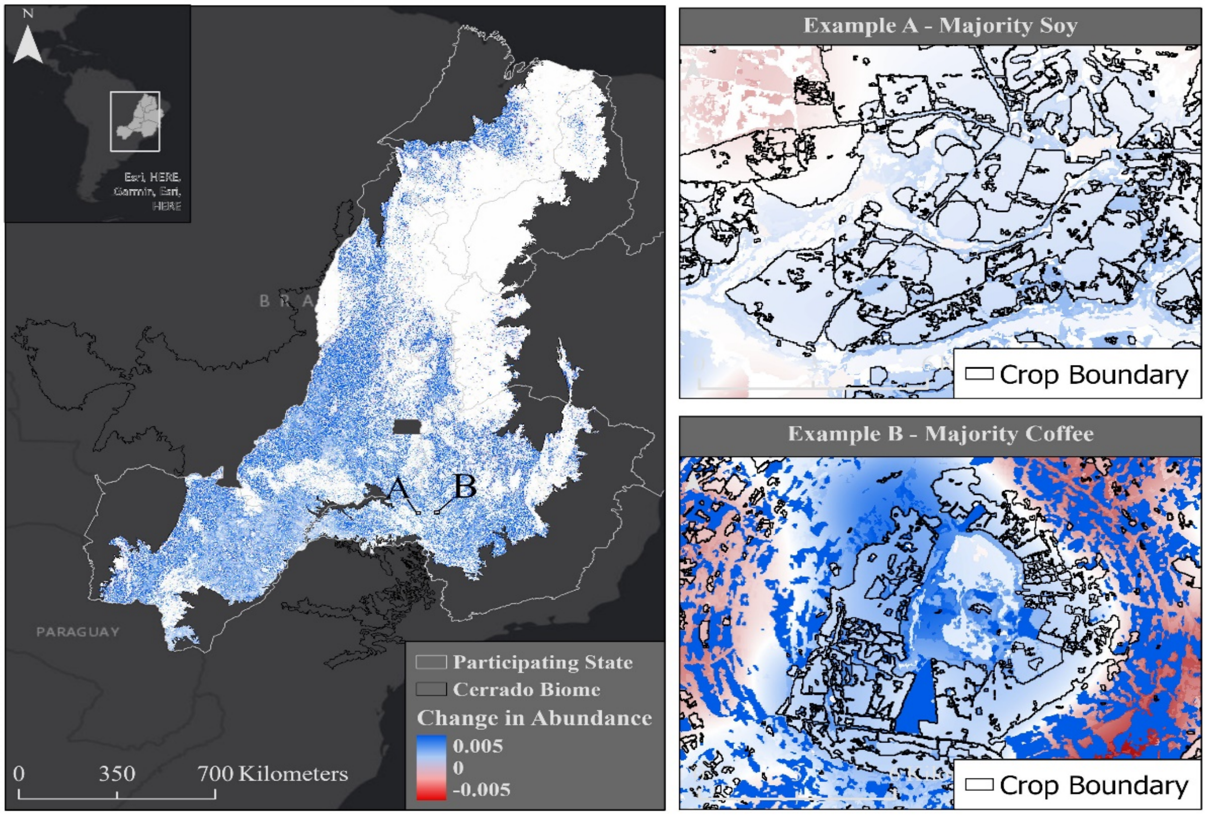
The InVEST Pollination model produces a map of relative pollinator abundance between the two scenarios based on available nesting and foraging resources within the maximum flight distance of pollinator species. The InVEST model does not quantify an absolute or percentage change in pollinator abundance; that is, it does not measure the change in the size of the pollinator population. Instead, the model presents differences in pollinator abundance across specified scenarios based on an index score of 0–1. This should not be interpreted as a linear index (i.e., a change from 0.3 to 0.33 does not indicate a 10 percent increase in abundance). Rather, the intent of the model is to prioritize multiple land management scenarios based on relative influence on pollination services. Given this, the model is not well suited to evaluate the effects of the ILM Project on agricultural productivity in the region.[103]

Overall, the model demonstrates that pastureland restoration increases pollinator abundance (as characterized in the model inputs) and that these benefits improve agricultural productivity in neighboring crop fields, as shown in Figure 3.

In the participating states, the area of soy and coffee within the European honeybee's maximum flight distance from pasture was 234,275 hectares and 5,921,802 hectares, respectively. Based on the biome's landscape, 96 percent of coffee crops and 75 percent of soy crops are within pollinator flying distance of pastureland. Thus, restoration of pastureland is likely to support crop pollination. If all pastureland were restored, pollinators would have access to 75 percent of the soy crops and nearly all of the coffee crops in the biome. This may improve productivity of these crops and/or reduce the need for farmers to provide replacement pollination services for their crops.

The InVEST pollination model is a useful tool for qualitatively assessing geographic changes in pollinator abundance and informing landscape management scenarios. Pollinator abundance is quantified using a relative, non-linear index ranging from zero to one that can only be translated into pollinator population density with additional field data. Similarly, the InVEST pollination model supports modeling changes in agricultural yield, but also computes change on a relative, non-linear index ranging from 0 to 1. Connecting the index values to absolute changes in yield requires knowledge about the baseline crop species' yield within a field and the relationship between crop species' yield and pollinator abundance. We did not apply the optional agricultural yield outputs of this model because the relative changes in pollinator abundance could not be easily linked with percentage change in yield.

Exhibit 8. The Distribution of Pasture and Grassland in Participating States



SOURCE: IEC ANALYSIS USING INVEST POLLINATION MODEL, 2022.

Sub-Appendix 3C. Interviewees and Participants in Consultations

Table 1. List of DI interviews conducted

Organization	Designation	Name
FUNATURA	Gestor FIP Coordenação	Pedro Bruzzi
NSC	Diretor Executivo	Carlos Eduardo Marinelli
GIZ	Assessor Técnico da Cooperação Técnica	Adolfo Dalla Pria
GIZ	Diretor de Projeto	Taiguara Raoil Alencar
FUNATURA	Gestor FIP Coordenação	Pedro Bruzzi
INOCAS	Diretor Executivo	Johannes Zimpel
Centro de Agricultura Alternativa do Norte de Minas / DGM	Coordenador do Projeto DGM Brasil	Alvaro Carrara
Centro de Agricultura Alternativa do Norte de Minas / DGM	Consultora especializada em gestão socioambiental e gestão de projetos do DGM Brasil	Cláudia Calório
FUNATURA	Gestor FIP Coordenação	Pedro Bruzzi
FASE/MT	Coordenadora	Cidinha Moura
Associação da Comunidade Negra Rural do Quilombo Ribeirão da Mutuca/MT	Representante da Coordenação Nacional	Laura Silva
SENAR Diretoria de Educação Profissional Promoção Social	Coordenadora de Capacitação da Diretoria de ATeG	Janete Lacerda de Almeida
SENAR Coordenação de Projetos	Coordenador de Projetos/Coordenador de Monitoramento e Avaliação	Cristiane Edna Camboim
SENAR Coordenação de Projetos	Coordenador de projetos	Rafael Diego Nascimento da Costa
SENAR Coordenação de Projetos	Assessora da DATeG do Senar	Barbara Evelyn Magalhães Silva
SENAR TA Maranhão (Caxias and Vargem Grande regions)	Technical Assistant	Keyssyane
SENAR TA Minas Gerais (Triângulo)	Technical Assistant	Cristiano
SENAR TA Minas Gerais (Norte)	Technical Assistant	Edwaldo
Ministry of Environment	Programme Manager	Taiana Ramidoff
World Bank	Senior Agriculture Economist	Barbara Farinelli
World Bank	Senior Environmental Specialist	Bernadete Lange
World Bank	Operations Analyst	Daniella Ziller Arruda
*Note that the Ministry of Environment (MMA) requested FUNATURA participation in interviews and the Ministry of Agriculture (MAPA) expected interviews to be attended by SENAR.		

26 October 2021

Name	Organization	Project/Function
Pedro Bruzzi Lion	Funatura	Gestor FIP Coordenação
Thelma Lucchese Cheung	MAPA	FIP Paisagens Rurais
Francesca Belem Lopes Palmeira	Grupo NSC	FIP Avaliação - Consultora em Análises Estatísticas e Modelagem Ambiental
Alexandre Gessi	SENAR	FIP Paisagens Rurais / Coordenador de Salvaguardas
João Bruno Martins	SENAR-BA	FIP Paisagens Rurais/Supervisor/Bahia
Renata Villas Boas	Grupo NSC	FIP Avaliação - Consultora avaliação de resultados e impactos
Elisiane Sateles dos Santos	SENAR-BA	FIP Paisagens Rurais-Consultora-Bahia
Raiane Santos	INOCAS – MG	FIP Macaúba - Assistência Técnica INOCAS
Sunny Aaron Soares Silva	Senar Ba	FIP Paisagens Rurais- Coordenador

14 December 2021

Name	Organization	Project/Function
Pedro Bruzzi Lion	Funatura	Gestor FIP Coordenação
Marisete Catapan	Neotrópica	Co-moderadora
Marco Aurélio Santos da Silva	Hominus	FIPCar Minas Gerais - FIPCar PCT
Taiana Andrade Ramidoff	MMA	FIP Coordenação
Daniel Barbosa da Silva	MMA	FIP Coordenação
Jaine Ariély Cubas	MAPA	FIP CAR
Marcelo T. Rocha	Fábrica Ethica Brasil / Economia Industrial (IEc)	Consultor para avaliação dos impactos de desenvolvimento dos projetos apoiados pelos Fundos de Investimento Climático (CIFs)
Carlos Eduardo (Caê) Marinelli	Grupo NSC	Diretor Executivo
Renata Villas Boas	Grupo NSC	Consultora para avaliação de resultados e de Impacto dos projetos e do PIB
Francesca Belem Lopes Palmeira	Grupo NSC	Consultora em análises estatísticas
Carla Regina Mazzonetto Jacomini	BRASPLAN	Representante BRASPLAN
Márcia Catarina David	MMA	FIP Coordenação
Camila Santana	Banco Mundial	Comunicação - Banco Mundial
Alvaro Alves Carrara	CAA/NM	Coordenador Projeto DGM
Eliseu José Oliveira	CAA/NM	Diretor secretário
Joeliza Brito	CAA/NM	Diretora Financeira
Analia Aparecida da Silva	CGN/DGM Brasil/APOINME	Conselheira
Lucely Morais Pio	CGN/DGM Brasil/Articulação Pacari	Coordenadora
Maria do Socorro Teixeira Lima	CGN/ DGM Brasil/MIQCB	Conselheira
Srewe da Mata de Brito	CGN/ DGM Brasil/MOPIC	Conselheiro
Daniella ArrudaJanuário Tseredzaró Ruri-õ	Banco MundialCGN/ DGM Brasil/MOPIC	Conselheiro
Maria de Lourdes de Souza Nascimento	CGN/ DGM Brasil/Articulação Rosalino	Conselheiro
Gilberto Barros	CGN/ DGM Brasil/APOINME	Conselheiro
Mayk Honnie Gomes de Arruda	CGN/ DGM Brasil/Rede Cerrado	Conselheiro
Priscila Ayres Feller	CGN/ DGM Brasil/FUNAI	Conselheira
João Nonoy Krikati	CGN/ DGM Brasil/Vyty Cati	Conselheiro
Gabriel Costa Ribeiro	CAA NM	Secretário Executivo
Daniella Arruda	Banco Mundial	Gestora
Valcelio Figueredo	CGN/ DGM Brasil/Conselho Terena	Conselheiro

Endnotes

[1] For more details on Brazil's ABC Plan, see Sub-Appendix 3A.
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For more detailed information, see: Brazil Forest Reference Emission Level for reducing emission from deforestation in the Cerrado biome for results-based payments for REDD+ under UNFCCC (2017). Available at: https://redd.unfccc.int/files/frelcerrado_en_20170629_br_v.2.pdf
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[17] World Bank (2018) Integrated Landscape Management in the Cerrado Biome Project, 27
[18] https://projects.worldbank.org/en/projects-operations/project-detail/P164602
[19] CEPF, 2017
[20] Feltran-Barbieri and Féres, 2021
[21] Sharp et al, 2020
[22] BIP, 24
[23] DGM project 004 recording.
[24] DGM project 016 recording.
[25] Souza, Geraldo & Gomes, Eliane & Freitas, Antonio & Fernandes, Paulo & Camboim, Cristiane. (2021). Assessing the Impact of the ABC Cerrado Project. Pesquisa Agropecuária Tropical.
[26] The World Bank High-Level Commission on Carbon Prices, chaired by World Bank Chief Economist Nicholas Stern and Nobel Laureate Josh Stiglitz, estimated that carbon prices of at least US$40–80/t$CO_2$ by 2020 and US$50–100/t$CO_2$ by 2030 are required to cost-effectively reduce emissions in line with the temperature goals of the Paris Agreement. As such, $40 is a conservative value of carbon. Report available at: https://static1.squarespace.com/static/54ff9c5ce4b0a53decccfb4c/t/59b7f2409f8dce5316811916/1505227332748/CarbonPricing_FullReport.pdf
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[29] Implementation Completion and Results Report (2020) Sustainable Production in areas Previously Converted to Agricultural Use Project, 18
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[32] Interview data.
[33] Interview data.
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[36] World Bank (2018) Integrated Landscape Management in the Cerrado Biome Project
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[44] Estanislau, P. (2021) Spatial Distribution of Agricultural Farms led by Women
[45] Estanislau, P. (2021) Spatial Distribution of Agricultural Farms led by Women
[46] Implementation Completion and Results Report (2020) Sustainable Production in areas Previously Converted to Agricultural Use Project, 15
[47] BR DGM for Indigenous People and Traditional Communities Implementation Status & Results Report Octover 2021
[48] For full story, see https://www.youtube.com/watch?v=ISE5q3aPL6c
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[50] Climate Investment Funds (2012). Brazil Investment Plan, 42
[51] Interview data.
[52] Implementation Completion and Results Report (2020) Sustainable Production in areas Previously Converted to Agricultural Use Project, 26
[53] Grupo NSC Natureza, Sociedad e Conservação (2021) Progress Evaluation: Product 2
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[55] Implementation Completion and Results Report (2020) Sustainable Production in areas Previously Converted to Agricultural Use Project, 26
[56] World Bank (2015) Project Appraisal Document: Dedicated Grant Mechanism for Indigenous Peoples Project
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[58] Grupo NSC Natureza, Sociedad e Conservação (2021) Progress Evaluation: Product 2, 144
[59] Implementation Completion and Results Report (2020) Sustainable Production in areas Previously Converted to Agricultural Use Project
[60] Interview data.
[61] Climate Investment Funds (2012). Brazil Investment Plan, 37
[62] Implementation Completion and Results Report (2020) Sustainable Production in areas Previously Converted to Agricultural Use Project
[63] BR DGM for Indigenous People and Traditional Communities Implementation Status & Results Report Octover 2021
[64] World Bank (2015) Project Appraisal Document: Dedicated Grant Mechanism for Indigenous Peoples Project, 40
[65] (DGM 250 CIMQCB Babassu recording)
[66] World Bank (2015) Project Appraisal Document: Dedicated Grant Mechanism for Indigenous Peoples Project
[67] Implementation Completion and Results Report (2020) Sustainable Production in areas Previously Converted to Agricultural Use Project.
[68] Interview data.
[69] Climate Investment Funds (2012). Brazil Investment Plan, 24
[70] Interview data.
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[72] Implementation Completion and Results Report (2020) Sustainable Production in areas Previously Converted to Agricultural Use Project, 12.
[73] Climate Investment Funds (2012). Brazil Investment Plan, 38
[74] Climate Investment Funds (2012). Brazil Investment Plan
[75] DGM project 004 recording
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[78] All reviewed DGM project recordings
[79] ABC PAD
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[100] Hipólito et al. (2019). Valuing nature's contribution to people.
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[102] Pires, Carmen et al. 2014. Selection of bee species for environmental risk assessment of GM cotton in the Brazilian Cerrado. *Pesquisa Agropecuária Brasileira*.
[103] Beyond the InVEST framework, data limitations preclude a quantitative assessment of pollination and other ecosystem services of the ILM project, including the specific locations of the pastureland restoration projects and the specific restoration activities being implemented.

4. Brazil Light-Touch Case Study: Development of a Macaúba-Based Silvopastoral System and Value Chain

Project Details	Funding
Project Name: Macaúba-based Silvopastoral System Project **Country:** Brazil **CIF Program Area:** Forest Investment Program (FIP) **Bank approval:** July 2017 **Effective since:** July 2017 **Actual closing:** December 2022 **MDBs:** Inter-American Development Bank (IDB)	**Total Value:**[1] $6 million CIF: $3 million (FIP equity investment) **Multilateral Investment Fund (MIF):** $1.326 million (reimbursable technical cooperation) **Counterpart:** $1 million (local investors) **Co-financing:** $0.643 million **Instrument type:** Equity, loan, reimbursable grant **Sector:** Private

Key Highlights

- The Macaúba Project is a US$6 million investment, with an innovative financing structure including a direct equity investment channeled through the MIF/IDB Lab, to develop a Macaúba, palm-based silvopastoral system and value chain.

Topline Findings on Development Impacts

- **Biodiversity protection:** The project has planted 2,475 hectares of Macaúba, with 340 farmers and their families, establishing 114 ecological corridors to protect local biodiversity and sequestering 34,292 tons of CO_2. The goal is to plant 30,000 hectares of Macaúba by 2030.
- **Increased farmers' income**: Farmers confirmed that the Macaúba Project was expected to increase revenue and income, with a guaranteed annual price of $74/ton, corrected for inflation. Additional income is expected from intercropping, with 10 farmers having signed contracts for planting crops, such as cassava, on 288 hectares.
- **Employment:** Macaúba harvesting provides employment opportunities outside of the regular coffee season in the region. Direct employment by Innovative Oil and Carbon Solutions (INOCAS) has already increased from eight to 26. The full-time employment equivalent is expected to grow to 226 by 2048. Many of these workers are hired from the local prison and provided a normal wage.
- **Land restoration:** The planting of Macaúba promotes land restoration and helps farmers avoid some of the negative impacts of climate change. The project contributes to the achievement of Brazil's Nationally Determined Contribution (NDC), with an estimated 933,750 tons of carbon sequestered in 20 years. If the INOCAS project were replicated on 25 percent of the degraded pastures of the Cerrado, it would fully cover Brazil's NDC commitment.

Climate Investment Context & Overview

The Cerrado biome, located in the eastern highlands of Brazil, stocks 9 billion tons (Gt) of carbon in its primary vegetation, hosts 4,200 endemic species, and is responsible for 12 percent of global soybean production.[1] The region suffers higher deforestation rates than the Amazon. As of 2018, nearly half of the Cerrado had been converted to pasture (29.5 percent) or cropland. Between 2016 and 2017, the region lost 14,185 square kilometers of native vegetation.[2]

In the project region of Minas Gerais, farmers depend on monoculture cattle farming. The lack of diversification and non-agricultural economic opportunities encourages deforestation to increase pasture sizes and makes smallholders even more vulnerable to pests, soil degradation, and income volatility. Cattle production also harms the environment, as land degradation and deforestation reduce carbon capture by forests and soil, increase water runoff, and add to erosion. Farmers are increasingly exposed to climate change impacts, including heat and drought, and are also seeing a deterioration in soil fertility.[3]

The Macaúba palm tree, native to Brazil, grows outside of typical rainforest zones and can be planted in agroforestry schemes, meaning in a land use system in which trees or shrubs are grown around or among crops or pastureland. It represents an alternative to palm oil, which is grown in Brazil in large monoculture palm plantations. Palm oil and soy production have both contributed significantly to deforestation in Brazil, including in the Cerrado.

The Macaúba produces similar oil to the African oil palm, but is more drought-resistant and does not require rainforest conditions. Macaúba can produce palm oil to sustainably meet rising domestic and global demand without the need for land use change, and without reducing the yield of pastures for cattle grazing. Macaúba fruit is processed into vegetable oil, animal feed, and a dense biomass granulate. Even though Macaúba naturally thrives in Brazil, especially in the Cerrado, it remains largely unexplored, as it has lacked a structured commercial value chain. The Macaúba has a high potential for oil production and for diversification of byproducts with some potential of value aggregation. Such a perennial and sustainable species has the potential to become an important new commercial oilseed crop. [4] The long-term Macaúba production potential in Brazil exceeds current global palm oil production volume and represents a potential source of meeting a large part of global demand. If this market could be proven, it could dramatically disrupt the global palm oil market and be scaled nationally and globally. Unlike palm oil, Macaúba requires no forest clearing and is planted within existing pastures.

The growing global demand for vegetable oils for food and replacing fossil fuels has already led to increased oilseeds production. Almost 122 million tons of the 187 million tons of vegetable oils currently produced in the world come from palm and soybean oils. The oil palm is cultivated in tropical latitudes, in areas formerly occupied by forests, and soybean oil is a by-product of protein meal production. The diversification of raw materials for the vegetable oil market is thus strategic for both food and non-food sectors.[5] The Macaúba business plan therefore has potential anywhere in the rest of Brazil and the subregion where it grows naturally, so long as the supply-side issues are resolved (e.g. germination), interested farmers can be identified, the demand for vegetable oil continues, the government does not overly restrict its production, and additional finance can be attracted.

Project Objectives Related to CIF Financing

The project objective is to create the world's first sustainable Macaúba value chain with substantial social, environmental and economic impacts. Specifically, the Development of a Macaúba-based Silvopastoral System and Value Chain Project (the Macaúba Project) intends to achieve the following results:

- Establish 2,000 hectares of silvopastoral Macaúba plantations with 312 trees per hectare,
- Collect 1,500 tons of Macaúba fruits per year,
- Sequester 600,000 tons of carbon dioxide equivalent (CO_2e), and
- Train 120 farmers on agroforestry systems.[6]

The project has a total financing volume of US$6 million, of which $3 million is non-grant funding endorsed by the Forest Investment Program (FIP) Private Sector Set-Aside (PSSA) that was initially designed as a loan. In 2016, this loan was changed to Multilateral Investment Fund (MIF) equity in an innovation based on the detailed analysis by the of the Inter-American Development Bank (IDB) Lab team. This solution meant the MIF/IDB Lab directly assumed the risk of the project, without needing to have a third-party financial entity as a partner, which would have been very challenging to identify given the unproven business model. Althelia Climate Fund was selected as the investment adviser to the MIF/IDB Lab. This was the first time that a FIP investment was channeled as equity shares of the private company executing the project.

An additional MIF reimbursable grant of $1 million helped provide training to farmers and laborers, structure the smallholder farmer involvement, and develop the business model. A small MIF grant covered costs associated with legal structuring and knowledge, coordination, and partnerships for scaling. Table 1 below summarizes the project budget.

Innovative Oil and Carbon Solutions (INOCAS), the lead firm, had to find an external co-financing contribution of over US$1 million. INOCAS turned to local Brazilian investors, Viveiro Nativo, Perfil Agricola, and Reinaldo Melo, who made investment commitments of over $1 million. The MIF/IDB Lab expects to exit this investment by year 10 (in 2028) when it becomes profitable. It plans to sell its shares to other interested investors or execute an exit option negotiated with INOCAS.

This project showcases a unique blended finance structure: the use of MIF/IDB Lab reimbursable and non-reimbursable grants; equity share investments from the FIP, channeled through the MIF/IDB Lab; and a counterpart contribution through equity shares investments from local partners with an interest in the development of the Macaúba value chain. While the project has not yet reached maturity, blended finance is proving to be a successful resource to jump-start the first Macaúba value chain intended for mass commercialization and to de-risk future investments. Based on IDB calculations, the project is expected to generate return on equity per year of $1,109, increasing to $22,183 in 2028.[7]

Table 2. Macaúba Project Budget Breakdown

Financing	USD	%
Equity (FIP under MIF management)	3,000,000	50%
Reimbursable technical cooperation	1,000,000	17%
Non-reimbursable technical cooperation	106,000	2%
Other (legal and structuring)	220,000	4%
Total MIF Funding	**4,326,000**	**73%**
Counterpart (local investors)	1,000,000	17%
Co-financing	643,000	10%
Total Project Budget	**5,969,000**	**100%**

Source: MIF (2017) Development of a Macaúba-Based Sylvopastoral System and Value Chain. MIF's Private Sector FIP proposal. Washington, DC: Multilateral Investment Fund.

Project Stakeholders

The primary beneficiaries of the Macaúba Project are harvest workers and smallholder farmers, including 400 smallholder farmers and harvest workers on about 2,000 hectares of degraded pastureland.[8] The project focuses on farmers who are certified as smallholders by the government, which requires being small, family-run, and deriving income mainly from agriculture. The farmers and harvesters are predominantly male (72 percent of harvest workers). The project also reached out to landless people (*assentados*) through a representative organization to gauge their interest in planting Macaúba, and employs prisoners through a local partnership with the Association for the Protection and Assistance of the Convicted (APAC) to work on the extraction of Macaúba coconut seeds for the production of seedlings.[9]

INOCAS is a start-up firm that is implementing agricultural concepts allowing for a sustainable production of plant oils and resulting in significant carbon sequestration. When INOCAS established its Brazilian subsidiary in 2015, there were no other Macaúba projects. INOCAS expects the Macaúba project to be profitable, breaking even after seven years and starting to show both a stable annual turnover of a minimum of US$ 4.4 million and a stable EBITDA of a minimum of US$ 2 million in 2018.

National project partners are also key stakeholders in implementation, not only in financing INOCAS. Viveiro Nativo made an in-kind investment by providing Macaúba seedlings. INOCAS first worked with a privately owned pilot processing plant capable of processing the current, naturally occurring harvest, but has already set up a small-scale processing plant for the additional volumes of Macaúba produced. A large industrial processing facility will be set up with professional partners later and will be financed through different resources.

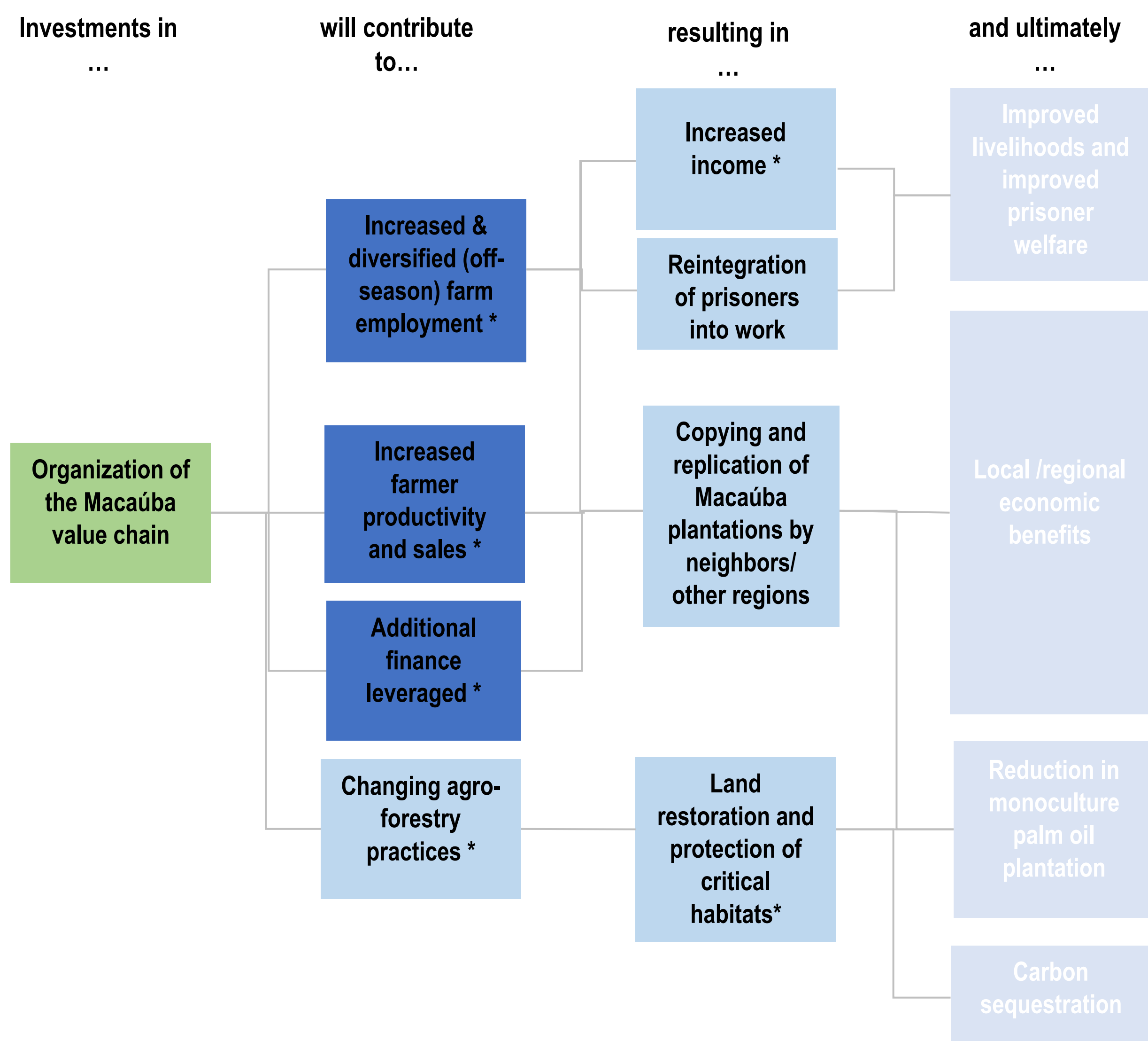
In addition to investors, INOCAS partners with several Brazilian government agencies and research institutions. The Companhia Nacional de Abastecimento (CONAB) is a critical partner securing a minimum price for Macaúba. The Instituto Agronômico de Campinas (IAC) and the Universidade Federal de Viçosa (UFV) were engaged to tackle the germination challenge, as the seedlings proved difficult to grow. Finally, INOCAS also works closely with the Ministry of Environment.[10]

Development Impact Pathways and Case Study Focus

The purpose of this case study is to analyze the developmental impacts (DIs) of the FIP investment in the Macaúba value chain in Brazil. The project's impact pathways are presented in Figure 1. The objective of the project is to create the world's first sustainable Macaúba value chain, with substantial social, environmental, and economic impacts.[11]

The project aims to prove the commercial viability of a silvopastoral Macaúba system so that it can scale nationally and internationally. The project is expected to generate employment, increase income, and diversify income sources for smallholder farmers and harvest workers during periods of high seasonal unemployment, while at the same time contributing to climate change mitigation by capturing a significant amount of CO_2 and contributing to a reduction of land use change in an area of deforestation.

Figure 1. Impact pathways of the Macaúba value chain



The **dark blue boxes** indicate the DIs quantitatively addressed in this case study: farm productivity and sales, additional leveraged finance, and seasonal farm employment. The **light blue boxes** indicate the DIs qualitatively addressed in this case study: increased income and improved livelihoods, the reintegration of prisoners into work, copying and replication of the Macaúba plantations, changing agro-forestry practices, land restoration and protection of critical habitats.

The **gray boxes** indicate DIs that should follow from the investments, but are either only estimated, or too long-term to assess currently, as it takes the Macaúba tree five years to mature. Some would require additional research and analysis to address—specifically: long-term improvements in income and livelihoods, including for the prisoners hired for the Macaúba harvesting; reduction in monoculture palm oil plantation; carbon sequestration; and broader economic benefits.

Of these DIs, most are already included in the project approval documents (as indicated by the asterisk); Table 2 provides details. The market effects, such as leveraging of additional finance, were less emphasized as they were beyond the scope of the current investment. This project also contributes to the MIF's Climate-Smart Agriculture (CSA) Aspirational Indicator of reducing the gap between high- and low-productivity agricultural firms by half in 10 years while mitigating climate change.

Table 3. Macaúba Project DI Measurement

DI	In Project Documents?	Tracked by Project?
ENVIRONMENTAL		
Hectares of silvopastoral Macaúba plantations	Yes	Yes
Number of trees per hectare	Yes	Yes
Soil quality	Yes	Yes
Erosion	Yes (qualitative)	Yes (qualitative)
Water consumption of cows	Yes	No
Temperature reduction, due to shade provided	Yes	No
Carbon sequestration	Yes	Yes
ECONOMIC		
Number of farmers and harvesters trained	Yes	Yes
Tons of Macaúba fruits collected per year	Yes	Yes
Total factor productivity (Macaúba outputs required minimal increase in inputs (labor, fertilizer, but no additional land)).	Yes	Yes
Additional partnerships, with a view to expansion	Yes	Yes
Additional leveraged finance leveraged	Yes	Yes
SOCIAL		
Land lease payments	Yes	Yes
Payments per ton of Macaúba fruits harvested from their land	Yes	Yes
Harvest workers' average incomes during the Macaúba harvest season	Yes	Yes

Development Impacts: Performance to Date

Land restoration

By December 2022, INOCAS had planted 2,475 hectares of Macaúba, with 340 farmers and their families.[12,13] The ultimate aim is to plant 30,000 hectares of Macaúba by 2030, but this target requires financing beyond the current project.

Figure 2. Implementation Progress by End of 2022

Increased farm productivity

The Macaúba can produce about 1 ton of oil and 1.8 tons of fodder per hectare. Soy, which is currently the primary plant used for biofuel in Brazil, produces only 0.6 tons of oil per hectare. Although Macaúba productivity is lower than the average for palm oil in Brazil (2 tons per hectare), research shows that the Macaúba yield can increase to between 2.5 tons of oil per hectare planted with 400 trees and 5 tons per hectare with improved seed selection, the identification of healthy, viable and disease-free seeds for the palm trees.[14]

While the production of seedlings was initially the main bottleneck in the process, INOCAS was able to overcome this barrier and produce enough seedlings to meet both farmer demand and its targets through partnerships to improve the related technology and its own laboratory. Using a new germination protocol, INOCAS can now achieve an over 50 percent germination rate for the Macaúba seedlings.[15] The seedling production target for 2021 was 750,000 seedlings.[16] Ultimately, INOCAS aims to produce 1,000,000 seedlings to contribute to broader expansion across Brazil.[17]

Actual harvesting is only recently ramping up, as it takes five years for the Macaúba palm to become productive. By March 2020, 207,000 tons of Macaúba fruit had been collected from wild Macaúba palm trees. By October 2021, in the first month of the harvest, 160 tons had been collected by 14 harvesters.

Additional farmer income

The Macaúba tree offers additional income to farmers, notably outside of the coffee season, as the Macaúba harvest takes place between October and December. When the Macaúba palm becomes productive in the fifth year after planting, INOCAS buys Macaúba from the farmers for an annually fixed, inflation-corrected price, removing market risk. There is a 50:50 division of profits between INOCAS and the farmers.[18]

Based on INOCAS estimates, one day of wild harvesting generates approximately 1 ton of Macaúba fruits per person. The harvest is sold to the INOCAS oil mill at $47/ton.[19] With an additional subsidy by CONAB of $57, the farmer makes $74/ton (in 2022).[20] The additional subsidy to provide a fixed price to farmers is critical to eliminate the risk in investing in a new, unproven species. As the project is still new, it will be required over the long-term. This was confirmed on the INOCAS Instagram page as the price paid per ton of Macaúba delivered to its factory.[21] All of the farmer statements confirmed that the Macaúba project was expected to increase revenues and income.[22] Based on IDB estimates, gross farmer revenue is expected to grow from $26,016 in year 1 to $265,598 in year 20.[23]

Additional income may also be made from intercropping. Belterra is a partner company of INOCAS in the implementation of agroforestry systems with Macaúba. There are already 10 farms with signed contracts for planting crops such as cassava on 288 hectares, generating a new source of income for Belterra and the farmers.[24] Intercropping also substantially increases soil quality, with purposeful planting of legumes with this in mind.

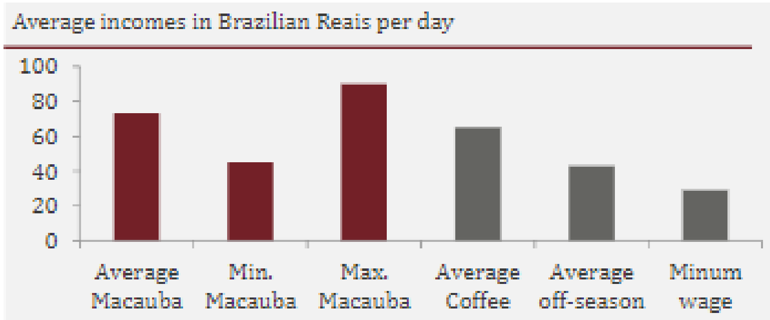
Seasonal job creation for harvesters and additional income

An estimated 200,000 people work in the coffee sector in Minas Gerais during the harvest period from September to January.[25] At the end of the season, unemployment goes up significantly. The Macaúba fruit is harvested outside of the coffee season (October to December), providing off-season employment opportunities. Agroforestry and silvopastoral systems[26] also require more labor than pastureland.

The number of workers hired by INOCAS to support the farmers during the harvest had increased from eight to 26 by 2022.[27] The full-time equivalent is expected to grow from 26 in 2013 (Year 5) to 226 in 2030 (Year 30), based on IDB calculations.[28] Through a partnership with the Association for the Protection and Assistance of the Convicted (APAC), many of these workers are hired from the local prison and provided a normal wage, in line with local regulations. The prisoners are also able to reduce their sentence through this work (by one day for every three days worked).[29]

The 2012–2013 feasibility study determined that the Macaúba harvest workers in the project area reported earnings that are, on average, more than twice the minimum wage and significantly more than in potential alternative jobs during the off-season (see graph below).

Figure 3. Comparison of Average Income (R$) per Day



Source: Macaúba feasibility study 2013.

An average household's income was $211 per month during the year from non-Macaúba activities, with the minimum wage being $161 per person per month.[30] During the Macaúba harvesting season, the average income from Macaúba was $417 per person per month. All the harvesters interviewed also said they wanted to work in the Macaúba harvest the next year.[31] These estimates from the feasibility study are likely to be realized, as the study was conducted in the same geographic area, with the same type of farmers.

Reintegration of prisoners into work and improved prisoner welfare

INOCAS has a partnership with APAC to promote the resocialization and professionalization of inmates through work in the project. In 2021, there were 12 workers from the prison, and the number was expected to grow to 50 in the near future.[32] This is about half of the single prison's population. The prisoners receive minimum wage, with 25 percent retained by the prison for the institution's maintenance and 75 percent transferred to the inmates' account. The relationship between INOCAS and prisoners has been successful. According to interviews with INOCAS employees, the prisoners are twice as productive as other workers. Some elements of society remain skeptical, feeling that prisoners should be punished.[33] However, additional companies are also beginning to partner with APAC as a replication effect of the successful partnership between INOCAS and APAC.

CO_2 sequestration

An estimated 20.75 tons of carbon are sequestered per hectare each year.[34] So far, 24,743 tons of CO_2 have been sequestered by the project. An expanded Macaúba value chain could also contribute to Brazil's Nationally Determined Contribution (NDC), including the reduction of greenhouse gas (GHG) emissions to 43 percent below 2005 levels by 2030, as unsustainable land use and agriculture are the main contributors to the country's GHG emissions. If the INOCAS project were replicated in 25 percent of the degraded pastures in the Cerrado, it would fully meet Brazil's NDC commitment.[35]

Table 4. Summary of Quantified Benefits

DI	Included in original project documents?	Metric /KPI	Method of assessment
Farm productivity & sales	Yes	Tons of Macaúba fruit collected	Calculation of sales, based on tons of fruit collected X established price
Seasonal job creation and related income	Yes	Number of seasonal jobs	Counting of jobs, based on human resource records, (also using full time equivalent)
Additional leveraged finance	No	Amount of financing mobilized	Reported by INOCAS as financing above and beyond the original project budget

Other Implied DI Benefits (Not Assessed)

Increased value of land

The value of the land of those planting Macaúba has already increased. Based on one farmer, farm value doubled. While the farmer had bought the plot for $779 per hectare, he was now receiving offers for $2,596 per hectare.[36] Based on interview data, this was arguably a general effect, with land value increasing up to 50 percent or even higher.[37]

Land restoration, microclimate and diversification of crops

Land restoration is a major, anticipated DI of the investment, helping farmers avoid some of the negative impacts of climate change, including from heat and drought, as well as from soil degradation.[38] The Macaúba palm corrects the acidity of soil in pastureland, improving the growth and quality (e.g., color, less lignite, nutritional protein value) of the grass.[39] Soil improvement is further accelerated by related agronomic practices and intercropping schemes.

The shade of Macaúba palms provides shelter for cattle and creates a microclimate that has additional benefits for soil and grass quality. While it is too early to assess, the health of cattle and the quality of meat are expected to improve**.** Farm productivity hypothetically can also be increased to an estimated five times higher density of cattle.[40] One reason the health of cattle is expected to improve is reduced temperature stress (it takes a cow 12 hours to recover from heat stress), meaning they produce more meat and milk. Planting Macaúba also serves as a barrier for erosion, with more stable soils improving the infiltration of water, as evidenced in the soils and on water springs in the vicinity of the farms.

It is too early to assess the extent that planting Macaúba has resulted in the diversification of crop production, with related improvement in soil quality. INOCAS is gathering soil quality data, taking soil samples as baseline and subsequently, every two years.[41] Overall, the baseline situation of the degraded lands was sandy, stony soils, with minimal water that was only suitable for the planting of crops such as cassava. The Macaúba plantations are now mixed with seasonal crops including pineapples, beans, sweet potatoes, cassava, pumpkin, rice, watermelon, and peanuts; even corn can be intercropped with Macaúba. So far, an estimated third of smallholders are intercropping. Ultimately, these productivity improvements may also have nutritional benefits for the farmers, surrounding communities and wider consumers.

Protection of critical habitats

The creation of ecological corridors is one of the project's key performance indicators. So far, 114 ecological corridors have been established in line with the related government regulations on Permanent Preservation areas (APP)/legal reserve. On average, for each farm there are two corridors linking forests, often along slopes and along water. There has been direct observation of the sound of birds and the passage of native species, birds, rodents and even panthers and anteaters under the shade of the palm trees. However, motivating farmers to rigorously collect related data to quantify the benefits has been challenging.[42]

Ecological corridor

Source: INOCAS

Catalyzing investment at scale

In addition to developing a Macaúba-based value chain, the project is expected to result in increased willingness of other financial actors to invest in this type of project in the future. INOCAS is already cooperating with Fundo Vale in Vale do Paraíba. Negotiations were concluded at the end of 2021 with the European fund Mirova Natural Capital and with AMAZ, for the planting of 5,000 hectares in four years, in the Northeast of Pará, expanding operations to the Amazon. The first 23 hectares have already been planted in early 2022.[43] It will be critical to add an indicator on the additional financing secured, with a view to assessing the uptake and scale of the pilot project and proposed business model.

Enabling Conditions and Barriers to Development Impacts

Ambitious, adaptive, and flexible management

INOCAS was willing to risk investing in a novel species. INOCAS showed leadership and resourcefulness when faced with unforeseen challenges, including a failure to meet the first planting season, a lack of engagement from stakeholders, unrealistic germination rate at project design, pests destroying 10 percent of the planted seedlings, and a dearth of investors. The company required ingenuity, entrepreneurship, and leadership skills, as well as resilience, tolerance for frustration, perseverance to endure and tackle many challenges, and a keen eye in seizing emerging opportunities.[44] INOCAS' ingenuity is demonstrated by the strategic shift to directly acquiring land,[45] previously considered out of scope, which entailed substantial social risks, including potential land disputes with farmers, that required careful management.

Expansion planning

INOCAS also had a clear, phased plan of expansion that included the germination of seedlings, starting from an existing nursery to fostering broader partnerships, and establishing its own lab. There were also early plans for the expansion from an existing oil mill, to its own oil mill, and finally to an industrial scale mill with separate investment. The MIF/IDB Lab also demonstrated similar incrementalism and flexibility when restructuring the financial agreement and converting the FIP investment from a loan to equity share.

Partnerships along the value chain

INOCAS fostered numerous partnerships along the value chain and remained open for new relationships. Fostering strong partnerships with multiple actors along the to-be-created Macaúba value chain, together with knowledge and information sharing, was critical to building the project's credibility.[46] INOCAS was well versed in the local culture and able to navigate the highly conservative attitudes in the local farming communities. "This was especially important in this context, as most participating farmers were small-scale and therefore need to see short-term benefits until the Macaúba trees started producing fruits," according to one interview.

The awareness and institutional capacity of the government to support this investment, most directly through CONAB, were also critical for securing the price for Macaúba that was not subject to initial market risk until the innovative business case was proven. It still remains to be seen whether the business case will be proven and the subsidy eventually, over the long term, phased out.

Scale-up of the Macaúba value chain is a prerequisite for attaining potential longer-term DIs that can result from the growth of this sector including reduced poverty and improved livelihoods, increased biofuel sector competitiveness, disruption of the palm oil market, reduction in monoculture palm oil plantations, and related carbon sequestration. However, several barriers to scale up remain, despite recent progress. Overall growth of the Macaúba value chain is constrained by the following barriers.

Limited knowledge and familiarity with the germination of Macaúba seedlings

This challenge has largely been overcome through cooperation with Brazilian research institutions and partnership with nurseries. INOCAS increased seedling production in 2021, due to the INOCAS laboratory and changes in the original germination protocol. Ultimately, seedling production was substantially diversified, and INOCAS is now exceeding seedling needs by producing enough for 500 hectares or more. INOCAS estimates it could plant up to 2 million seedlings on 5,000 hectares a year. [47]

Challenges working through local cooperatives

Initially, INOCAS was to partner with Coopatos, a local milk cooperative, but there was low appetite for the risks involved.[48] Instead, INOCAS opted to work directly with farmers. Nevertheless, there is good contact with the local associations, notably as a conduit to the communities. The association president invites INOCAS to meetings and farmers learn about Macaúba. As INOCAS plans its expansion to the Amazon, it is also planning a stronger partnership with a local harvesting cooperative.[49]

Reluctance of conservative cattle farmers to innovate and high opportunity costs to setting aside land

Three years are required for the Macaúba palm plants to be large enough to no longer be attractive to hungry cattle. Through extensive communication and awareness-raising efforts, INOCAS was able to identify sufficient farmers to fulfill the project's targets,[50] but much broader uptake at scale is still required to demonstrate the value of the innovation and to move beyond early adopters. Creating sufficient incentives by paying for the maintenance of the saplings prior to them becoming productive, diversifying their sources of revenue, and developing markets for Macaúba byproducts have been important for encouraging broader uptake.[51] Due to the high cost of fencing and low cost of land, farmers have been planting on unused or additional, purchased land, instead of existing holdings.[52] The opportunity costs of using existing, productive land, remain high, due to the time required for Macaúba to become productive. Generally, as supply increases, it will be important to review the extent to which there is adequate market demand for future Macaúba products, and whether increased supply will affect price and therefore the degree of attractiveness to smallholders.[53]

Establishment of the commercial processing and market for Macaúba products

INOCAS was keenly aware of the risks related to processing and marketing and managed them through incremental growth; the harvesting the fruit of wild Macaúba trees, upgrading and existing mill and storage, and providing test volumes of Macaúba products to companies.[54] The diversification of Macaúba products into two types of oil, two types of animal fodder, and granulate taps into and also increases the existing local market when the prospects of the use of Macaúba as biofuel still seem a distant prospect. Nevertheless, the business case for the commercial production of these products at scale is not yet fully proven. The value chain has been identified and is being tested, but is not fully commercially established at this early stage of development. It is remains relatively early still to assess the processing capacity and market for the actual Macaúba products.

Limited access to finance

Limited access to finance was a substantial barrier due to the perceived investment risk in nature and biodiversity conservation, an untested technology, and a young start-up. Investors were cautious to fund innovative vegetable oil projects with novel species after recent experiences with Jatropha projects that did not ultimately yield the expected oil volumes. Commercial financing, specifically bank loans, was not available due to the 15- to 20-year horizon of the investment and INOCAS' lack of a track record. Revenues are nonexistent until the fifth year, because it takes about five years to get to the first harvest. Since break-even is not expected until year 7 and stable cash flow of over US$1 million until after year 10, the internal rate of return on cash flows before financing would be negative for 10 years, about 10 percent over 15 years, and 15 percent over 20 years.[55] This financing challenge is slowly being overcome, as demonstrated by the proof-of-concept, growing cash flow and ultimately the ability of INOCAS to leverage additional partnerships and additional growth capital.

Negative perceptions of biofuels

Biofuel production is often associated with unsustainable demand for land and other negative environmental and social impacts. Those impacts include contributions to further deforestation, water depletion and pollution, soil degradation, nutrient depletion, and the loss of wild and agricultural biodiversity, as well as displacement of the rural poor. INOCAS has sought to address these concerns upfront with strict land use requirements: “It is a hard requirement that INOCAS will only work with and support smallholder farmers who plant Macaúba on pastureland in a silvopastoral system. This is included in the project requirements as negotiated with IDB/MIF and it will also be a requirement in the contract between INOCAS and the participating farmers. Thus, inside the scope of the project, it can be assured that no additional forest will be cleared for Macaúba.”[56]

Ensuring fair labor conditions

Access to harvesters and fair labor conditions are a major cost factor and potential barrier. However, Brazil’s national labor laws are strong, and the INOCAS human resources conditions are compliant with local legislation. Harvest workers earn a living wage harvesting Macaúba. Since they are paid per kilogram of fruit collected, rather than an hourly or daily rate, the earnings of individual workers are monitored to ensure that all earn at least the minimum wage. At the end of 2021, INOCAS was also drafting the health and safety documentation for harvest workers. Since the data collection for this evaluation, INOCAS has installed an ombudsman and a “contact us” page on its website, where suggestions and complaints are collected, registered, and dealt with.

Gender equality

Gender inclusion has been a challenge and a weak point of the project. Inside the company, there are no women on the INOCAS board, and the company has faced challenges finding female candidates for positions. Most recently, only 20 out of 500 CVs for the position of financial director were submitted by women.[57] At the farm level, while farms are often in the name of the husband, contracts are signed with the household, usually both husband and wife. Fieldwork is mostly done by women, with an estimated one-third of related workers being female, and women performing better than men on tasks such as planting seedlings and harvesting.[58] Nevertheless, more than 70 percent of harvesters are still men, which is also due to the arduous nature of the work and cultural barriers.

Regulatory framework

The regulatory framework remains challenging to navigate. While there is a state-level framework (the 2011 Pro Macaúba Law) that encourages cultivating, extracting, marketing, and consuming Macaúba products, INOCAS has faced regulatory hurdles. For example, the classification of the Macaúba as native trees prevents them from being cut down.

There are also very strong regulatory restrictions on the sale of oilseed to biofuel companies in Brazil. INOCAS is trying to become a member of the Brazilian Social Fuel Seal Program (Selo Combustíve Social) to get access for smallholders in biodiesel feedstock production. Generally, INOCAS is working closely with the government, especially with the Ministry of Environment, participating in monthly meetings and networking with other similar projects. Government financing was not an option for Macaúba, due to the novelty and untested nature of the sector (unlike, for example, eucalyptus).

CIF’s Role in Realizing DIs

FIP financing, notably the innovative equity financing model, was critical for providing the initial capital required for proof-of-concept and viability of the Macaúba Project business model. Without FIP financing, the project would not have been able to identify and attract the initial capital required to kick-start the project, as other efforts had previously failed due to the substantial risks involved in investing in a novel species and an untested start-up company. The financing model was also critical for attracting additional private sector financing, initially from local investors, to the project, as well as post-project.

Future Opportunities for Realizing DIs through the Macaúba Value Chain

Replication of Macaúba plantations by neighbors/other regions/countries

The demonstration of the large-scale feasibility and economic attractiveness of the silvopastoral model is one of the main objectives and challenges of this innovative pilot project. Pasture area in Brazil totaled about 170 million hectares in 2010. If 50 percent of those pastures were converted into silvopastoral systems with 200–300 palms per hectare, Macaúba oil production could exceed today's global palm oil production.[59] The Macaúba palm grows also at least in Argentina, Bolivia, Colombia, Guyana, Mexico, Paraguay, Suriname, Uruguay, and some countries in Central America. They could substantially benefit from both the agronomic and business lessons of the project.

Copying and replication effects by neighboring farmers are critical to scaling impact. "Some farmers became early adopters, experimenting with the Macaúba trees on their farms. The adoption grew year after year, as more farmers joined. The farmers who first joined, were followed in many cases by their neighbors, who soon also saw the benefits of cultivating Macaúba. Eventually, a critical mass of farmers emerged, who inspired others to join too." [60]

INOCAS is planning to scale up operations beyond the FIP intervention. The goal is to expand beyond the 2,000 hectares starting in 2021, and to expand by 1,000 hectares per year thereafter, with its own cash flow. INOCAS aims to plant 30,000 hectares by 2030, which requires substantial additional investment. INOCAS also intends to raise additional finance to build its own Macaúba processing factory, which will require a US$4 million investment. These additional investments will also attract more companies to the market, resulting in further de-risking and growth of outside investment. Investors have shown great interest in financing new plantations in exchange for carbon credits.[61] In the long term, the objective is for INOCAS to become a large-scale supplier of an environmentally friendly substitute to palm oil for the Brazilian market.

Creation of a sustainable food and aviation fuel market

The main aim of INOCAS is to provide Brazilian consumers with carbon-neutral meat and milk, as well as biofuels (e.g., Natura) for various industrial purposes. The original ambition of the initial research was to test the possibility of utilizing the Macaúba for biofuels for the airline industry. While for many years, low global oil prices did not provide sufficient incentives to move in this direction, the recent increase in oil prices, the commitment of airlines to aggressive emission reduction targets, and the uptick in global travel following the eventual lifting of travel restrictions may change this. The global sustainable aviation fuel market was valued at $72.1 million in 2020 and is projected to reach $6.2 billion by 2030, registering a CAGR of 56.4 percent from 2021 to 2030.[62]

Gender and social inclusion

INOCAS should make further efforts to ensure women are hired among its own staff, as well as for the wider labor force, ensuring that women harvesters have fair and equitable working conditions, including attention to specific issues, such as the potential for gender based violence in rural, agricultural activities. It should also make sure that the use of prison labor aligns fully with the ILO Forced Labour Convention.

Reduction in deforestation

In the longer term, the shift from palm oil and soya to Macaúba may indirectly contribute to the reduction of deforestation and recovery of the landscape (see estimates above on the potential disruption to the global palm oil market).

Future Research

CIF should consider additional research to facilitate analysis of additional DIs associated with the Macaúba value chain in Brazil.

- Collection of additional data on the leveraging of finance and other scaling effects including uptake by other farmers in other regions of the country and broader region.
- Promoting the identification and harmonization of shared biodiversity metrics to ensure full transparency and credibility of financial, environmental and social impacts with a view to attracting future investors.
- Tracking of any potential unplanned, negative environmental or social effects of the project, including an assessment of submitted grievances, once the mechanism is in place.
- Eventual assessment of the innovative financing model, including the exit option.

Table 5. Interviewee list

Organization	Position	Name
INOCAS	CEO	Johannes Zimpel
IDB	Lead Investment Officer	Dieter Wittkowski
IDB	Senior Investment Officer	Felipe Cresciulo
Funatural	FIP Coordinator	Pedro Bruzzi
Ministry of Environment		Antonio Sanches
Ministry of Environment		Clarisse Cruz

Endnotes

[1] Praveen Noojipady et al., 2017, "Forest carbon emissions from cropland expansion in the Brazilian Cerrado biome," Environmental Resource Letters 12(2).
[2] MIF (2017) Development of a Macaúba-Based Sylvopastoral System and Value Chain. MIF's Private Sector FIP proposal. Washington, DC: Multilateral Investment Fund. Available at: http://pubdocs.worldbank.org/en/535621531831072433/1966-PFIPBR501A-Brazil-Project-Document.pdf.
[3] MIF (2017).
[4] Colombo, Carlos & Berton, Luiz & Diaz, Brenda & Ferrari, Roseli. (2017). Macaúba: A promising tropical palm for the production of vegetable oil. OCL. 25. 10.1051/ocl/2017038.
[5] Colombo et al. (2017).
[6] MIF (2017) Development of a Macaúba-Based Sylvopastoral System and Value Chain.
[7] Throughout this case study, values were converted from Brazilian Real to U.S. Dollars. Where a conversion is noted, the conversion factor used is US$1 to R$ 0.25957827. This value is the average of the daily closing rate from 1/1/2015 to 12/31/2021 according to Wall Street Journal Markets Data. This average reflects the period from the founding of INOCAS's Brazilian subsidiary to the most recently reported numbers. Data was accessed at https://www.wsj.com/market-data/quotes/fx/BRLUSD/historical-prices.
[8] MIF (2017) Development of a Macaúba-Based Sylvopastoral System and Value Chain.
[9] MIF (2017).
[10] Interview data.
[11] MIF (2017) Development of a Macaúba-Based Sylvopastoral System and Value Chain.
[12] In 2020, 23 were smallholder farms and three were large rural producers. The average size of smallholder farms was 58 hectares and the average size of large rural properties was 867 hectares. The total average size of project farms was 155 hectares. CIF (2020) Building a Macaúba-Based Silvopastoral System and Value Chain: CIF-GDI Delivery Challenge Case Study.
[13] In Val do Paraiba both silvopastoral systems and two agroforestry practices, with coffee and bananas, were planned. Due to an adjustment to the strategy, INOCAS was also planting Macaúba on 400 hectares it had leased itself. Quarterly Report November 2021.
[14] INOCAS feasibility study.
[15] Quarterly Report August 2021
[16] INOCAS Instagram post, Jan. 25, 2021.
[17] Interview data.
[18] Interview data.
[19] Converted from Brazilian Real.
[20]Converted from Brazilian Real.
[21] INOCAS Instagram post, Aug. 25, 2021.
[22] Farmer statements from producer Daniel Lúcio Pinto, INOCAS Instagram post, March 18, 2021; producer Alderico Aniceto Ferreira, INOCAS, March 23, 2021; producer José Augusto Filho, INOCAS Instagram, April 6, 2021.
[23] Converted from Brazilian Real. IDB estimates, impact calculations shared with the consultant.
[24] INOCAS Instagram post, Dec. 11, 2020.
[25] INOCAS feasibility study.
[26] Agroforestry involves integrating trees with crop production, while silvopastoral systems integrate trees and forests with livestock production. Both practices provide important opportunities for increasing agricultural productivity and environmental sustainability. See, e.g., https://www.omicsonline.org/scientific-reports/AGT-SR163.pdf.
[27] INOCAS Quarterly Report November 2021.
[28] IDB estimates.
[29] INOCAS addition of data.
[30] Converted from Brazilian Real.
[31] Converted from Brazilian Real. Source: INOCAS feasibility study.
[32] Interview data.
[33] Interview data.
[34] Imaflore (2020). Carbon Sequestration of INOCAS Macaúba Plantations in Brazil.
[35] Cava, Pilon, Ribeiro, et al. (2017), as cited in IDB (2021), Impact Investment for Biodiversity Conservation. Cases from Latin America and the Caribbean, 37.
[36] Converted from Brazilian Real.

[37] Interview data.
[38] IDB (2021). Impact Investment for Biodiversity Conservation.
[39] Interview data.
[40] The information in this paragraph is drawn from interviews.
[41] The information in this paragraph is drawn from interviews.
[42] Interview data.
[43] Interview data and supplementary information provided through written comments by INOCAS.
[44] IDB (2021). Impact Investment for Biodiversity Conservation.
[45] Interview data.
[46] IDB (2021). Impact Investment for Biodiversity Conservation.
[47] Interview data.
[48] IDB (2021) Impact Investment for Biodiversity Conservation.
[49] Interview data.
[50] Interview data.
[51] IDB (2021) Impact Investment for Biodiversity Conservation.
[52] Interview data.
[53] IDB (2021). Impact Investment for Biodiversity Conservation.
[54] IDB (2021).
[55] IDB (2021).
[56] The information in this paragraph is drawn from interviews.
[57] Interview data.
[58] The information in this paragraph is drawn from interviews.
[59] See https://pubdocs.worldbank.org/en/304631613740088773/PFIPBR501A-Comments.pdf.
[60] Interview data.
[61] INOCAS written comments.
[62] See https://www.prnewswire.com/news-releases/sustainable-aviation-fuel-market-to-reach-usd-6-261-9-million-by-2030--registering-a-cagr-of-56-4---valuates-reports-301378840.html.

5. India Light-Touch Case Study: Scaling Up Solar Power Technologies

Project Details	Funding
Name: Clean Technology Fund Investment Plan for India (including seven projects) **Country:** India **CIF Program Area:** Clean Technology Fund (CTF) **Bank approval:** *see Table 3 for individual project dates* **Effective since:** *see Table 3 for individual project dates* **Expected closing:** *see Table 3 for individual project dates* **MDBs:** Asian Development Bank (ADB) and World Bank	**Total Value:** $7,539 million **CIF:** $723 million **Co-financing:** $6,816 million **MDB:** $1,630 million **Government of India:** $1,010 million **Other:** $4,176 million **Instrument type:** Loan, grant **Sector:** Public

Key Highlights

- CIF created a $723 million Clean Technology Fund (CTF) Investment Plan for India focused on scaling up renewable technologies, with an additional $6,816 million of co-financing from multilateral development banks (MDBs), the Government of India, private lenders, and bilateral agencies.
- The CTF Investment Plan contains seven distinct programs. This case study emphasizes the development impacts of two that were funded partly through CTF: the ADB's Solar Park Transmission and the World Bank's Grid-Connected Rooftop Solar programs.

Topline Findings on Development Impacts

- **Market development:** The seven programs have leveraged $2.45 billion in co-financing and have played a catalytic role developing investors' interest in solar rooftop and solar park projects and improving financing conditions.
- **Local job creation**: The two solar rooftop programs are estimated to have so far created about 9,604 direct jobs (i.e., construction and maintenance) and 950 indirect jobs (i.e., manufacturing of equipment) in the solar rooftop industry. Job creation is not estimated for the other programs.
- **Increased energy access and reliability:** The seven projects have provided an additional 11,787 GWh of power annually; this additional energy supply is expected to benefit 770,000 households in India annually.
- **Energy security:** By replacing fossil-sourced energy with solar power, the seven projects have avoided the annual consumption of about 4.7 million tons of coal and 1.0 tons of oil equivalent (toe) of diesel.

- **Reduction of GHG emissions and air pollutants:** The displacement of fossil energy with solar energy from these seven projects has so far led to the avoidance of about 10.4 million tCO_2e as well as 14.6 kt SO_2, 6.2 kt NOx and 1.4 kt $PM_{2.5}$ annually. The seven projects are estimated to avoid $946 million of emissions-related costs annually.
- **Health benefits:** The seven projects are estimated to avoid $1.36 billion of health-related costs annually, which is mostly from costs related to respiratory diseases from particulate matter.
- **Other DIs:** Additional benefits include increased gender equality through new job opportunities and improved access to essential services.

Climate Investment Context and Overview

India has made significant improvements in meeting its growing energy demand, increasing its installed capacity by over 35 percent between 2014 and 2021 and thus reducing energy and peak power deficits while enhancing electricity access. At the end of 2021, India's power system included about 393 GW of installed capacity.[1] However, India is still largely dependent on fossil fuels, with 60 percent of capacity sourced from coal, lignite, gas, and diesel. Further, population growth, a growing manufacturing sector,[2] urbanization, increased grid access and an increasing standard of living are increasing the pressure on India's energy sector.[3]

To meet energy demand sustainably, the Government of India (GoI) established a target to reach 550 GW of installed renewable generation capacity[4] by 2030—up from 150 GW in 2021.[5] Given India's significant solar potential, with about 5,000 trillion kWh radiating over the country each year,[6] solar power is expected to be the primary energy source in meeting this target. Many opportunities exist to take advantage of India's solar potential, including the development of (mega) solar parks[7] and rooftop solar PV for residential, industrial, and commercial buildings.

The GoI has also made considerable progress in energy access. Within the last decade, India has connected almost half a billion people to electricity, with 96.7% of Indian households connected to the grid and 0.33% relying on off-grid electricity sources.[8] However, reliability, affordability, and sustainability of energy access remain significant issues;[9] 2.4% of households in India remain without electricity, mainly concentrated in rural regions including Uttar Pradesh, Madhya Pradesh, Rajasthan, and Bihar.[10]

Although India has significantly increased its renewable energy sources (RES) capacity, barriers remain in the RES sector. Constructing solar parks requires significant time and money to acquire suitable land and receive the required clearances. As solar parks tend to be in remote areas, additional basic infrastructure construction is sometimes necessary (e.g., water access, road connectivity, and telecommunications),[11] and solar parks often have limited access to transmission networks, making it difficult to feed power into the grid. Lack of debt financing and limited consumer awareness about solar rooftop PV have also hindered growth in this sector. In particular, the poor financial health of India's electricity distribution companies (DISCOMs) is a significant challenge in India's energy transition. Integrating renewables into the energy system will strain DISCOMs' ability to forecast costs and revenue streams and further impact their financial stability.[12]

Project Objectives Related to CIF Financing

The Clean Technology Fund (CTF) Investment Plan for India was endorsed in 2011, totaling $723 million allocated to help India reach its renewable energy ambitions (Table 1). The CTF investments are supplemented with $6,816 million of co-financing from ADB and the World Bank International Bank for Reconstruction and Development (IBRD), the GoI, and other sources (i.e., private lenders and bilateral agencies). In 2015, after India raised its target for installed solar from 20 GW by 2022, to 100 GW—60 GW of ground-mounted utility scale solar power and 40 GW of rooftop solar installations—the plan was revised accordingly. (As of November 2022, actual installed solar capacity was just under 62 GW.[13])

Table 6 Overview of Project Financing Plans for India's CTF Projects

Program	MDB[14]	Project Financing (USD million)				
		CTF	MDB	GoI	Other	Total
Innovation in Solar Power and Hybrid Technologies	IBRD	50	150	200	0	**400**
Development Policy Loan (DPL) to Promote Inclusive Green Growth and Sustainable Development in Himachal Pradesh	IBRD	100	100	185	1,958	**2,343**
Rajasthan Renewable Energy Transmission Investment Program	ADB	198	300	300	0	**798**
Shared Infrastructure for Solar Parks – Phase I	IBRD	25	75	100	1,428	**1,628**
Solar Park Transmission	ADB	50	175	225	0	**450**
Solar Rooftop Investment Program	ADB	175	330	0	500	**1,005**
Grid-Connected Rooftop Solar Program	IBRD	125	500	0	290	**915**
	Total	**723**	**1,630**	**1,010**	**4,176**	**7,539**

Source: World Bank and ADB project documents and the 2021 CTF Results Report.

The CTF Investment Plan consists of seven programs related to renewable energy investments, focusing on neutralizing the high costs of *mega* solar park projects and de-risking investments in rooftop solar photovoltaic (PV).[15] Table 2 provides an overview of the objectives and stakeholders of each CTF program in India.

Table 7 Overview of India's CTF Programs Related to Renewable Energy Investments

Program	Description	Borrowers (B) and Implementing Agency (IA)
Innovation in Solar Power and Hybrid Technologies	Demonstrate the viability of utility scale innovative renewable energy (RE) technologies and battery energy storage solutions (BESS) and strengthen institutional capacity so that these technologies can be commercially scaled-up.	B: Department of Economic Affairs IA: Solar Energy Corporation of India Limited
Development Policy Loan (DPL) to Promote Inclusive Green Growth and Sustainable Development in Himachal Pradesh	Improve the management of natural resources and promote inclusive green growth and sustainable development in Himachal Pradesh, including improving the environmental and social sustainability of hydropower.	IA: Department of Environment, Science and Technology (DEST) and Government of Himachal Pradesh
Rajasthan Renewable Energy Transmission Investment Program	Support the development of transmission facilities to evacuate RE to the state and national grid from new solar parks being developed in Rajasthan.	IA: Government of Rajasthan Energy Department and Rajasthan Rajya Vidyut Prasaran Nigam Ltd. (RRVPNL – state transmission company)

Program	Description	Borrowers (B) and Implementing Agency (IA)
Shared Infrastructure for Solar Parks – Phase I	Support the development of large-scale solar parks by investing in shared infrastructure (e.g., access to roads, water supply, telecommunication, etc.) and providing technical assistance.	B & IA: Indian Renewable Energy Development Agency Limited
Solar Park Transmission	Support the development of high-voltage transmission systems for the evacuation of electricity generated by new solar parks to the interstate grid.	B & IA: Power Grid Corporation of India Limited (POWERGRID)
Solar Rooftop Investment Program	A multi-tranche financing facility to fund large solar rooftop systems for industrial and commercial buildings.	B & IA: Punjab National Bank (PNB)
Grid-Connected Rooftop Solar Program	Support the uptake of grid-connected rooftop solar photovoltaic (GRPV) by increasing available debt financing, improving institutional capacity, and increasing consumer awareness.	B & IA: State Bank of India (SBI).

Some of the seven programs are nationwide, while others are specific to certain regions in India (e.g., *Development Policy Loan to Promote Inclusive Green Growth and Sustainable Development in Himachal Pradesh Program* in Himachal Pradesh in North India). Solar park-related programs (*Rajasthan Renewable Energy Transmission Investment Program* and *Solar Park Transmission*) are based in Northwest India regions with particularly high solar potential. The interventions of the seven programs include loans (e.g., multi-tranche financing facilities, development policy loans) and grants for technical assistance.

Development Impact Pathways and Case Study Focus

The purpose of this case study is to evaluate the development impacts (DIs) of India's CTF programs related to investments in renewable energy projects. The renewable energy-related CTF programs in India are mainly focused on scaling up solar technologies to ultimately increase installed capacity and reduce greenhouse gas (GHG) emissions through large-scale solar parks (transmission) and solar rooftop PV. This case study provides a summary of the overall DIs for all of seven CTF programs, with a more in-depth view of two programs: *Solar Park Transmission* (ADB) and *Grid-Connected Rooftop Solar* (World Bank).

CTF investment plan for India development impacts

Overall, the seven CTF projects are expected to have the following development impacts:

Market development

These programs play a major role in developing the solar power market in India by reducing barriers to the market, making investments in solar power less risky, raising consumer awareness, and training financial and technical stakeholders.

Employment opportunities

Investment programs in the solar power market will provide direct jobs (e.g., construction and operation) and indirect jobs (e.g., equipment manufacturing and energy services, economic opportunities for local communities during the construction of projects).

Reduction of GHG emissions from fossil fuel use

As of 2018, India is the third-largest emitter of greenhouse gas (GHG) emissions,[16] after the United States and China. Half of India's emissions originate from the energy sector (1,173 Mt CO_2 in 2019).[17] The CTF investment programs are expected to reduce India's GHG emissions. Promoting solar energy development (from solar rooftop PV and solar parks) offers an alternative to fossil fuel energy and helps to prevent new coal power investments and displace diesel generation.

Increased electricity reliability

Installing solar rooftop PVs and connecting solar parks to the grid increases energy access. These projects are also expected to enhance reliability of the energy supply for essential service providers, such as hospitals and schools. Connecting more households to the grid (via the IBRD grid-connected rooftop solar project that finances installation to residential and commercial buildings) also provides a more reliable electricity supply for consumers.

Energy sector security and resilience

As India continues to grow in terms of its economy (i.e., industry) and population, achieving energy security is crucial to ensure reliable and accessible electricity. Investments in RES development (solar parks and rooftop solar PV) will improve India's energy security by diversifying India's energy supply and alleviating energy shortages.

Reduction of air pollutants from fossil fuel use and resulting health benefits

The displacement of fossil energy with solar power initiated by the CTF programs will reduce not only GHG emissions but also concentrations of other air pollutants[18] that can have a direct health impact, including particulate matter (PM), nitrogen oxides (NOx) and sulfur oxides (SOx). As electricity can be unreliable in India during the day, industrial buildings tend to have backup diesel generators. Solar rooftop PV can reduce the need for these generators by providing more reliable electricity during these peak hours and thus can reduce the amount of energy generated from diesel sources. This reduction can play a major role in reducing local air pollution created by these diesel generators.

Increased gender equality

The programs are expected to both directly and indirectly improve gender equality by creating job opportunities and training women in the solar energy market as well as indirectly providing access to essential services such as schools.

DI pathways for the Solar Park Transmission and the Grid-Connected Rooftop Solar projects

These two projects are emphasized in this case study because they provide a representative sample of the CTF Investment Plan for India. They are both at advanced stages of implementation (the solar park project ended in 2021), providing the opportunity to gain insights on actual development benefits from the implementing MDBs. Table 3 provides an overview.

Table 8. Overview of Selected Projects

	Solar Park Transmission (ADB)	Grid-Connected Rooftop Solar (World Bank)
Funding	$175 million ADB loan $50 million CTF loan $225 million from POWERGRID (equity, domestic bond issuance and other corporate loan financing)	$500 million World Bank loan $120 million CTF loan $5 million CTF grant $23 million Global Environment Facility (GEF) grant $267 million in private financing mobilized by SBI
Approved in	January 2016	May 2016
Effective since	May 2017	September 2016
Expected closing	September 2021[19]	November 2022
Objectives	Finance high-voltage transmission systems to evacuate electricity generated by new *mega* solar parks to the interstate grid and improve reliability of the national grid system	Increase the installed capacity of GRPV and strengthen relevant institutions for GRPV by increasing the availability of debt financing and building institutional and technical capacity as well as raising consumer awareness
Stakeholders	Borrower & implementing agency: Power Grid Corporation of India Limited (POWERGRID)	Borrower & implementing agency: SBI
Intervention	Project is based on sector loan approach and includes 4 subprojects in Rajasthan and Gujarat: 3 were connecting solar parks and one was updating equipment.	Project has two components: (1) Lending to increase GPRV installed capacity, and (2) technical assistance (TA) for digitalizing rooftop solar application and subsidy process, assisting bid process management, demand aggregation, devising innovative business models and capacity building. The program is nationwide, covering 17 states.
Goal	Improve the capacity of interstate transmission network, particularly for increasing electricity generated from solar parks to national grid. Originally forecasted to connect 2 GW of solar parks to the interstate transmission system. With the addition of new subprojects[20] in 2020,[21] the forecast was increased to 4.2 GW.	Install 400 MW of solar capacity from GRPV installations and strengthen institutional and technical capacity for relevant GRPV stakeholders.
Barriers addressed	• Time and expenses involved in obtaining suitable land in remote areas • Provides accessibility and promotes clearance for solar park projects	• Lack of commercial debt financing options for developers, installers, and aggregators • Lack of institutional and technical capacity • Lack of coordination between central and state government agencies as well as with private stakeholders • Low consumer awareness • Financial situation of DISCOMs

Based on the review of publicly available information about these two projects and interviews with key stakeholders, generic DI pathways were developed for utility-scale renewables and grid-connected rooftop solar PV (Figure 1). The **dark blue boxes** indicate the DIs that were quantitatively assessed:

- *Solar park transmission (utility-scale renewables):* Solar park market development, energy sector security and resilience (avoided fossil fuel consumption), increased electricity reliability, reduced GHG emissions and air pollutants from fossil fuel use, and associated health benefits; and

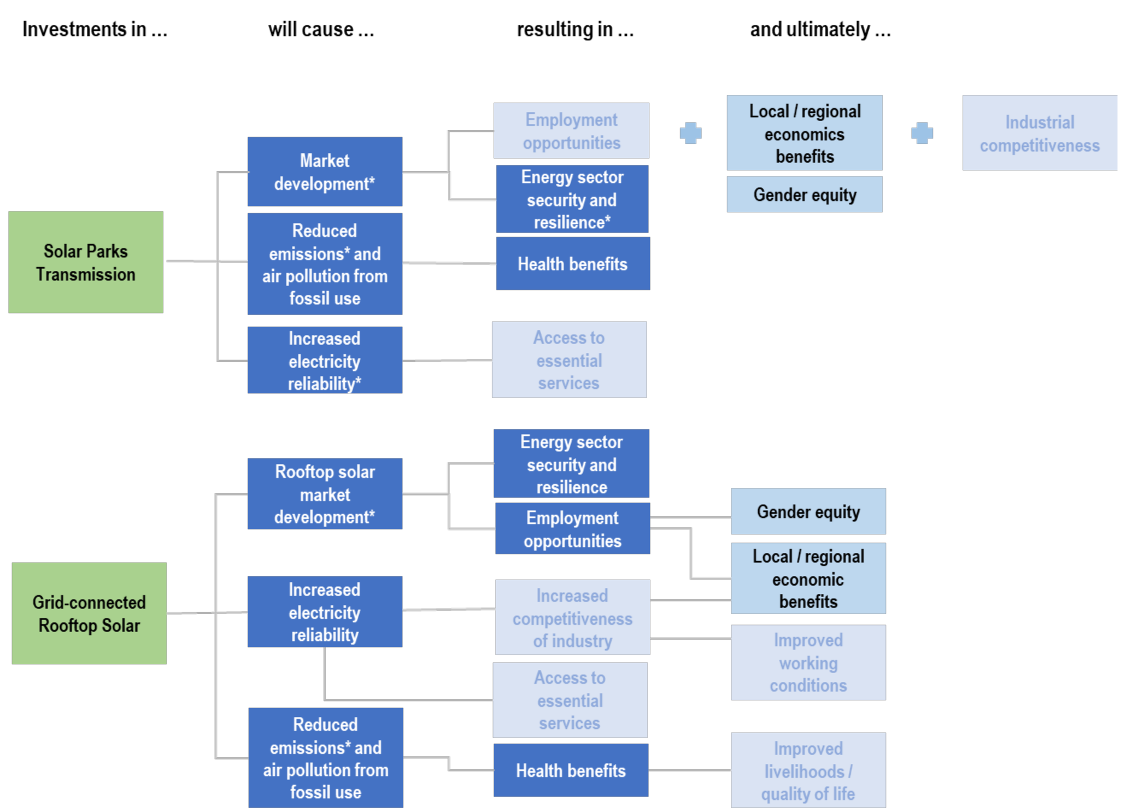
- *Grid-connected rooftop solar*: Market development, direct and indirect employment opportunities, energy sector security and resilience (avoided fossil fuel consumption), increased electricity reliability, reduced GHG emissions and air pollutants from fossil fuel use, and associated health benefits.

The **light blue boxes** indicate the DIs qualitatively addressed in this case study: local/regional economic benefits (e.g., gender equality—increase in employment opportunities for women and increased access for women to essential services). The **gray boxes** indicate DIs that should follow from the investments, but it is not possible to assess them because a) there is no available data and information (e.g., employment for solar park transmission); or b) they constitute long-term benefits that will only be visible in the years to come, or c) the assessment would require additional field research outside the scope of this light touch case study (e.g., improvement in access of essential services). Specifically:

- *Grid-Connected Rooftop Solar*: Increased competitiveness of Indian industrial users from enhanced access and supply reliability (constitutes long-term benefits, which would require both field research and modelling to isolate project benefits), improved working conditions (constitute long-term benefits and would require additional field research), and improved livelihood/quality of life (constitutes long-term benefits).

- *Solar Parks Transmission*: Employment opportunities, [22] industrial competitiveness (constitutes long-term benefits), and access to essential services (would require additional field research and constitutes long-term benefits).

Figure 4 Impact Pathways for India's CTF Programs Related to Renewable Energy



**These DIs are included in the project documents and have an associated metric. The metric for market development is the amount of financing mobilized in US dollars. The metric for reduced emissions is tCO_2e/year. The metric for more reliable electricity is the annual power generated (GWh/year) and number of residents supplied energy (ADB projects only). The metric for energy sector resilience is million tons of coal avoided per year (ADB projects only).*

Development Impacts: Quantified Results to Date

In this section, the quantitative results of the DIs of all seven CTF programs are provided, with more details specified for the two focus programs. Table 6 provides an overview of these results and Table 7 provides an overview of the methodologies used to derive these results.

Market development

The seven CTF programs are targeted to bring in a total of $6,816 million in co-financing. As of 2022, there has been $2,454 million of co-financing for these seven programs, based on the CTF 2021 Results Report and the most recent implementation results reports.

Interviewees from the World Bank stated the Grid-Connected Rooftop Solar Program has played a catalytic role in terms of making other financial players comfortable and improving financing conditions for rooftop solar developers, installers, and aggregators. They stated the program has indirectly mobilized around $4 billion into the solar rooftop market and been essential in scaling up the rooftop solar market.[23] The project enhanced the attractiveness of rooftop solar by improving its financial viability and carrying out a range of activities focused on enhancing consumer awareness and uptake. World Bank interviewees also observed that during the course of the program, the financing rate for rooftop solar projects declined significantly. It used to be around 16 percent in 2016, while now most lenders offer rates of 8–9 percent. It is challenging to estimate the direct impact that the program had on the financing rate for rooftop solar projects. However, World Bank stakeholders noted that the program, as the first mover, played a central role in de-risking the technology.

Similarly, interviewees at the ADB stated the Solar Park Transmission program has been influential in developing investors' appetite for solar park (transmission) projects and encouraging the public and private sectors to start similar projects. As of 2021, based on the CTF 2021 Results Report, the program has brought in $175 million in co-financing, and it is expected to bring in a total of $400 million in co-financing.

Energy sector security and resilience

The seven CTF programs in India are avoiding the consumption of 4.7 million tons of coal per year, as of 2022, assuming that 400 tons of coal are avoided for each GWh generated.[24] If the program targets for installed capacity are reached, the programs are expected to avoid 10.2 million tons of coal each year in total. Rooftop solar can be used as an alternative backup energy source during peak hours instead of diesel and therefore only 85 percent of the power generated from solar rooftop programs is taken into account for estimating avoided coal consumption.

The use of power generated from solar rooftop instead of diesel generators has led to the avoidance of about 1.0 tons of oil equivalent (toe) per year, as of 2022 (see Table 7 for estimation method). If the installed capacity targets for the solar rooftop programs are reached, these programs are expected to avoid 2.12 toe per year.

Employment opportunities

Renewable energy development in India is expected to have local direct and indirect job creation impacts, depending on the type of renewable energy technology. A co-benefits study[25] of job creation from renewable energy in India estimated the expected direct (e.g., construction and operation) and indirect (equipment manufacturing) job creation from various renewable energy technologies. The study estimated that rooftop solar directly creates 24.72 full-time equivalent (FTEs) per MW of installed capacity per year, and 2.5 FTEs/MW/year for ground mounted solar. Most of the direct employment comes from construction and installation, while a small portion comes from operations and maintenance. In addition, Council on Energy, Environment and Water (CEEW) experts estimate that about 2.6 FTEs/year are created for the manufacturing of solar power equipment, though this estimate can vary depending on production capacity.[26] Employment from the transmission and distribution phase has however not been estimated, posing an information gap.

As of 2022, the Grid-Connected Rooftop Solar Program has increased installed capacity by nearly 323 MW, translating to 9,035 direct jobs (construction and operation) and 950 indirect jobs (manufacturing of equipment). Based on this program's installed capacity target of 400 MW, the program should create 9,888 direct jobs and 1,040 indirect jobs.

Interviewees at the ADB noted it is difficult to estimate direct and indirect job creation associated with the Solar Park Transmission program, as it depends on several elements (i.e., the circumstances and environment of the project development area, capacity of developers and other relevant entities, size of the project, policies, etc.). However, they believe the project has generated a significant number of job opportunities during the construction and implementation of the transmission lines, in addition to creating indirect jobs in the solar industry (i.e., manufacturing and energy services).

Increased electricity reliability

The seven programs are expected to provide a total of 25,779 GWh per year of additional power generated (see Table 7 for estimation method),[27] and given the current estimates of actual installed capacity provided in the CTF 2021 Results Report and the most recent project intermediate results reports, the seven programs have delivered 11,787 GWh/year of additional generated power as of 2022. Based on the World Bank methodology,[28] this additional energy supply benefits about 3.7 million people[29] per year (or 774,000 households[30]). At the completion of these programs, there should be about 8.12 million residents (or 1.7 million households) benefiting from this additional energy supply.

The Grid-Connected Rooftop Solar Program has increased installed solar capacity by 366 MW and generated 532 GWh per year so far.[31] Based on the current installed capacity, it is providing energy access to an additional 160,000 people (about 34,000 households). Given the program's target to install 400 MW of capacity, the program would provide roughly 582 GWh/year and benefit 180,000 people (37,000 households).

By connecting solar parks to the grid, and thus enabling them to contribute to the electricity supply, the Solar Park Transmission program should lead to an additional 6,623 GWh of power generated per year, providing energy access to more than 2.1 million people (435,000 households). As the program's current installed capacity is unknown,[32] there are no estimates of the additional power generated.

Reduction of GHG emissions from fossil fuel use

India's seven CTF programs aim to reduce GHG emissions by about 24 million tCO_2e per year.[33] According to the CTF 2021 Results Report and the most recent project intermediate results reports, these programs have so far resulted in annual emissions reductions of at least 11 million tCO_2e. Data on GHG emissions are not available for all programs.

According to the CTF 2021 Results report, the Grid-Connected Rooftop Solar Program is expected to avoid 500,000 tCO_2e per year and 13.1 million tCO_2e of GHG emissions in total, assuming that solar rooftop PV will replace diesel (15–20 percent) and coal (85 percent) energy. According to the World Bank, the program avoided 866,488 tCO_2e of emissions from 2016 Q1 to 2021Q1 through the plants commissioned under the program.[34]

According to the ADB project documents and the CTF 2021 Results Report, the Solar Park Transmission program is expected to reduce emissions by at least 7.1 million tCO_2e per year and 177.5 million tCO_2e over 25 years, by feeding 4.2 GW of installed solar capacity to the national/state grid. These estimates do not include solar capacity displacing diesel backup generators used during peak demand. If included, the estimated GHG reduction would be almost double.[35] There is no data on the current actual emissions reduction, given that the installed capacity and actual power generation are unknown.

The avoided GHG emissions can be monetized by accounting for the related socioeconomic damages avoided. A study[36] reported the social cost of carbon emissions in India as \$86/tCO_2. As of 2022, the emissions reductions from the seven CTF programs are expected to avoid \$946 million in socioeconomic damages. Based on the emissions reduction targets, the Solar Park Transmission program is expected to reduce climate-related damages by \$607 million per year, and the Grid-Connected Rooftop Solar Program, by \$43 million per year.

Reduction of air pollutants from fossil fuel use

Based on the seven programs' estimated power generation from solar power and the assumed type of fossil fuel displacement (i.e., replacing coal and/or oil), the reductions in air pollutants are estimated using emission factors, particular to India's industrial oil use and use of coal for power. In total, the seven programs are estimated to lead to a reduction of 14.6 kt SO_2, 6.2 kt NOx and 1.38 kt $PM_{2.5}$ annually, as of 2022 (see Table 7 for estimation method).

By replacing electricity derived from coal and diesel with electricity sourced from solar rooftop PV, the Grid-Connected Rooftop Solar Program is estimated to have led to the avoidance of 0.61 kt SO_2, 0.27 kt NOx and 0.06 kt $PM_{2.5}$ of air pollution per year as of 2022. By replacing electricity derived from coal with electricity sourced from solar parks, the Solar Park Transmission program is expected to lead to annual reductions of 8.23 kt SO_2, 3.46 kt NOx and 0.78 kt $PM_{2.5}$ if the target for installed capacity is achieved. Since the current installed capacity and actual power generation are unknown for this program, estimates of actual reduction in air pollutants cannot be estimated.

Health benefits

The reduction in air pollutants resulting from the CTF programs will help to improve air quality and thus lead to health benefits for India. In 2019, 124 cities across 25 of India's 36 states and union territories were identified as having pollutant levels exceeding the National Ambient Air Quality Standards. In the same year, there were an estimated 1.2 million air pollution-related premature deaths in India.[37] More reliable and accessible electricity from solar parks and solar rooftop PV will also replace indoor lighting from candles and kerosene lamps, improving indoor air quality.[38]

The impact on health can be translated into monetary values based on the health costs avoided. A study by Trinomics[39] derives these monetary units based on the external health-related costs for India in terms of the cost per MWh of electricity generated per fuel type. Table 4 lists the health-related costs avoided when shifting from coal/oil-generated electricity to solar PV and their respective unit values.

Table 9 Health-Related Costs Avoided from Shifting from Coal/Oil to Solar PV

		Health-related costs avoided (USD/MWh)*	
Cause of health impact	**Impact on health**	**by shifting from coal to solar PV**	**By shifting from oil to solar PV**
Photochemical ozone depletion (smog)	Increase in certain types of cancer and diseases	2	0
Particulate matter	Increase in respiratory diseases	109	28
Human toxicity (non-cancer)	Increase in certain types of diseases	4	0
Human toxicity (cancer)	Increase in certain types of cancer	0	1

** Based on research from Trinomics (2020). Energy costs, taxes and the impact of government interventions on investments. Available at: http://trinomics.eu/wp-content/uploads/2020/11/Final-Report-External-Costs.pdf.*

Table 5 lists the total health-related costs avoided by the CTF programs by the type of costs. In 2022, the seven CTF programs are estimated to reduce health-related costs by $1.36 billion. The Grid-Connected Rooftop Solar Program is estimated to avoid $55 million of health-related costs every year. The Solar Park Transmission program is expected to avoid $768 million of health-related costs annually, if capacity targets are met.

Table 10. Total Health-Related Costs Avoided Annually (USD Million/Year)

	Solar Park Transmission		Grid-Connected Rooftop Solar Program		All seven CTF programs	
	Expected	Estimate	Expected	Estimate	Expected	Estimate
Photochemical ozone formation (smog)	13	-	1	1	49	22
Particulate matter	724	-	57	52	2,805	1,282
Human toxicity, non-cancer	29	-	0	0	6	3
Human toxicity, cancer	2	-	2	2	114	52
Total	768	-	60	55	2,974	1,360

Summary of Quantified DI Benefits Assessed

Table 6 provides an overview of all the targets and estimates as of 2022 for the quantified benefits of all the CTF India programs related to renewable energy investments. Installed solar capacity, GHG emissions avoided, and co-financing are derived from the CTF 2021 results report, and all other values are based on calculations using methodologies described in Table 7.

Table 11. Summary of DI Indicators for the CTF India Programs, Targets and Estimates as of 2022

Develop-mental Impact	Unit	CTF Programs	Innovations in Solar Power and Hybrid Technologies	DPL to Promote Inclusive Green Growth and Sustainable Development in Himachal Pradesh	Rajasthan Renewable Energy Transmission Investment Program	Shared Infrastructure for Solar Parks – Phase I	Solar Park Transmission	Solar Rooftop PV (Solar Rooftop Investment Program)	Solar Rooftop PV (Grid-Connected Rooftop Solar Program)	Total
Project Document source			WB	WB	ADB	WB	ADB	ADB	WB	
Installed RE capacity	MW	Target	400	1334	4300	2500*	4200	400	400	**13534**
		Estimate	0*	135	5000*	1000		23	366*	**6524**
Market development	Co-financing (USD million)	Target	350	2243	600	1603	400	830	790	**6816**
		Estimate		113	112	1650	175	28	376	**2454**
Energy sector security and resilience	Million tons of coal avoided per year	Expected	0.31	2.10	3.10	1.66	2.65	0.21	0.20	**10.2**
		Estimate	0	0.21	3.61	0.67		0.01	0.18	**4.7**
	Tons of diesel avoided per year (toe/year)	Expected	0	0	0	0	0	1.1	1.0	**2.1**
		Estimate	0	0	0	0		0.1	0.9	**1.0**
Employment opportunities	Direct jobs (FTEs)	Expected						9888	9888	**19776**
		Estimate						569	9035	**9604**
	Indirect jobs (FTEs)	Expected						1040	1040	**2080**
		Estimate						60	950	**1010**
Increased electricity reliability	Power generated (GWh/year)	Expected	765*	5259	7760	4161	6623	631	582	**25779**
		Estimate	0*	532	9023	1664		36	532	**11787**
	Million residents	Expected			9.00*		2.09	0.20	0.18	**8.12****
		Estimate						0.01	0.16	**3.71****
Reduced GHG emissions from fossil use	Annual $MtCO_2e$	Target	0.5	3.8	5.4	6.3*	7.1	0.4	0.5	**24.0**
		Estimate	0.0*	0.5	5.6*	4.9		0.03		**11.0**
	$MtCO_2$	Cumulative		2.8		6.7		0.07	0.9*	**10.4**
	Annual avoided emissions-related costs (USD million/yr)	Expected	41	325	464	542	607	38	43	**2061**
		Estimate	0	40	482	421		2		**946**
Reduced air pollution from fossil use	kt SO_2 per year	Expected	0.95	6.53	9.64	5.17	8.23	0.72	0.66	**31.90**
		Estimate	0.00	0.66	11.21	2.07		0.04	0.61	**14.59**
	kt NOx per year	Expected	0.40	2.74	4.05	2.17	3.46	0.32	0.30	**13.44**
		Estimate	0.00	0.28	4.71	0.87		0.02	0.27	**6.15**
	$PM_{2.5}$ per year	Expected	0.09	0.62	0.92	0.49	0.78	0.07	0.06	**3.03**
		Estimate	0.00	0.06	1.06	0.20		0.00	0.06	**1.38**
Health benefits	Annual avoided health-related costs (USD million/yr)	Expected	89	610	900	483	768	65	60	**2,974**
		Estimate	0	62	1046	193		4	55	**1,360**

*WB: World Bank; ADB: Asian Development Bank. * These statistics were derived from the project documents, whereas the other estimates are provided by the CTF 2021 results report or calculated using a methodology described in Table 7. Whether the data come from ADB or the World Bank is indicated at the top of the table. **This total is estimated for additional energy access, assuming that the transmission and distribution loss for all programs is 10%, the % of residential energy usage is 35% and the energy consumption per capita is 1000 kWh. Underlined impacts come from data from CTF, ADB and World Bank documents, whereas the other impacts are based on calculations using methods described in Table 7.*

Table 12. Development Impact Methodologies

DIs	Included in original project documents?	Metric /KPI	Method of assessment
Installed RES capacity	Yes	MW	Provided in project documents and CTF results report
Market development	Yes	Amount of financing mobilized ($)	Provided in project documents and CTF results report
Employment opportunities	No	Rooftop solar job creation (FTEs)	Quantitative analysis using job factors from a CEEW study on co-benefits of RES development in India on employment
Energy security	ADB: Yes WB: No	Million tons of coal avoided per year	Based on methodology used by the ADB projects: using power generation and assumption of 400 tons of coal per GWh. Value is multiplied by the estimated % of the power generated replacing coal. According to World Bank stakeholders, 85% of power generated from solar rooftop replaces coal; the rest replaces diesel power generated. For other programs, it is assumed that all power generated replaces coal. *T of coal = GWh/yr * 400 * % of coal replacement*
	No	Tons of diesel avoided per year	For rooftop solar programs, it is assumed that 15% of the power generated replaces diesel. It is assumed that 0.01163 tons of oil equivalent are avoided per GWh. *T of oil = GWh/yr *0.01163 * % of oil replacement*
Increased electricity reliability	ADB: Yes WB: No	Annual power generation (GWh/year)	Based on methodology used by the ADB projects: *GWh/yr = [(MW x 8760)/1000] * capacity factor (provided by project documents)*
		No. of residents supplied energy	Based on the methodology used by the ADB projects: using annual power generation and assumed transmission and distribution (T&D) losses (provided by project documents), 35% residential energy use (REU) and energy consumption of 1,000 kWh per capita (based on GoI's target for provided energy use). *# of residents = [GWh/yr*(1-T&D loss) *% REU]/ GWh p.c.*
Reduction of GHG emissions from fossil use	Yes	Annual GHG emissions reduction (tCO_2e/year)	Provided in project documents and CTF results report
	No	Annual avoided emissions-related costs (USD million/yr)	Based on the social carbon cost (SCC) in India ($86/$tCO_2$) from literature. *SCC avoided = annual emissions reduction ($MtCO_2$) * $86/$tCO_2$*
Reduction in air pollution from fossil use	No	kt SO_2/year, kt NOx/year, kt $PM_{2.5}$/year	Based on emissions factors derived from the IEA's World Energy Outlook 2020, assumption about fossil fuel displacement ratios (85:15 for coal/oil in solar rooftop projects and 100:0 in all other projects) and the estimated power generation. *kt/year = [(coal emission factor (kt/PJ)) *(power generation (PJ/year))*% coal replacement] + [(oil emission factor (kt/PJ))*(power generation (PJ/year))*% oil replacement]*
Health benefits	No	Annual avoided health-related costs (USD million/yr)	Based on the value of specific health-related costs from literature. The values are based on the difference in the monetary values (€/MWh) for each type of external costs between coal/oil and solar PV generation. *health unit cost (HUC, coal/oil) = coal/oil HUC – solar PV HUC (€/MWh)* *Reduction in health costs = annual power generation (MWh/year) * {[(HUC, coal) *(% coal replacement)]+ [(HUC, oil)*(% oil replacement)]}*

Other Implied DI Benefits (Qualitatively assessed)

India's CTF programs could have additional development impacts that were not quantifiably addressed in this case study due to limitations such as the timeframe of impacts, the scale of the project, or the need for additional research/analysis. This section describes additional DIs that are expected, but could only be assessed qualitatively based on a literature review and interviews with stakeholders.

Increased gender equity

India ranks 140th out of 153 countries on the World Economic Forum's Global Gender Gap Index 2021 in terms of offering equal opportunities to women and men.[40] Some of India's CTF programs have included specific gender-based requirements to improve gender equality within the renewable energy sector. The investment programs can also benefit women indirectly with more reliable electricity improving access to essential services such as educational infrastructure.

All gender-related benefits from the Solar Park Transmission program are expected to be indirect. Women account for only 11 percent of the workforce in the rooftop solar sector in India, while the global average is 32 percent.[41] Women's participation in this sector is higher in the design, pre-construction phase and corporate positions, versus on-site functions (construction, operation, and maintenance). The lack of women's participation in this sector is due to minimal opportunities because of safety and security concerns at rooftop solar sites and misconceptions about women's capabilities.[42] As of November 2020, part of the technical assistance (TA) provided by the Grid-Connected Rooftop Solar program, including the training of 316 staff members from the State Bank of India Rooftop Solar Program, included 33 women trained. The program is also expected to benefit women and children indirectly due to increased electricity access and reliability.

Enabling Conditions for Development Impacts

Several enabling conditions were identified in the Grid-Connected Rooftop Solar Program and the Solar Park Transmission program that helped unlock DIs through the creation and scale-up of the renewables market—leading to employment opportunities, energy sector resilience and local/regional economic benefits; and increasing renewable electricity capacity, leading to reduced emissions and air pollutants, health benefits, more reliable electricity, and increased access to essential services.

Government support

India's policy measures and renewable energy targets have encouraged the uptake of rooftop solar and aided the development of solar parks. For solar transmission projects, state governments play a key role in facilitating land procurement. This facilitation occurs more frequently in states where renewable energy is already greatly developed.[43] Notably, the Model Rooftop Solar Regulations by the Forum of Regulators has enabled Indian states to adopt key features of the model regulation. Also, the technical assistance from the Grid-Connected Rooftop Solar Program has helped to change existing state regulations by incorporating consumer- and utility-centric business models.

RESCO ecosystems

The Grid-Connected Rooftop Solar Program helped develop a Renewable Energy Service Company[44] (RESCO) ecosystem by enabling firms to bring in equity from international investors, raising about $1 billion during the project.[45] RESCOs can aggregate demand and provide the benefits of economies of scale.[46] RESCOs also have the incentive to ensure high quality installation and thus provide quality assurances. The program has been a major workstream and has created a platform for new developers.

Outreach programs to promote GRPV

The Grid-Connected Rooftop Solar Program has benefitted from cooperation with important stakeholders to connect with residential and micro, small, and medium enterprises (MSME) through the technical assistance component. For instance, SBI has reached out to MSMEs (specifically to capital expenditure (CAPEX) and RESCO borrowers) with awareness campaigns about the benefits of GRPV and has provided specialized financing products. The program also cooperated with DISCOMs to create business models and promote rooftop solar systems to consumers. The program worked with the GoI to spread awareness through informational campaigns and created a streamlined application process for installing residential solar rooftop PV (currently running in 14 states and being developed in three other states).

Credit guarantee mechanism for MSMEs

While there is a large potential for rooftop solar development among MSMEs, they tend to lack the credit ratings needed to gain access to sufficient financing. Credit guarantee schemes have played an important role in incentivizing investors to support MSME solar rooftop projects in the Grid-Connected Rooftop Solar Program.

Barriers to Scaling-up Solar Power Technologies in India and Realizing DIs

Scaling up solar power technologies is essential for the realization and continuation of DIs resulting from solar power market development in India, including jobs, local/regional benefits, and greater use of RES, leading to reductions in GHG emissions and air pollution, and more reliable electricity.

Although the two programs studied in depth have been quite successful, the process of implementing them has revealed several barriers for these types of solar power technology developments. In particular, the Grid-Connected Rooftop Solar Program identified several barriers for solar rooftop technologies, as discussed below.

Financial barriers

The financial health of DISCOMs: DISCOMs do not have the financial and technical capacity to deal with increasing renewables (i.e., increased energy variability). Some state-owned DISCOMs have poor financial health and are discouraged from adopting net metering and other GRPV policies. The COVID-19 pandemic has put additional strain on these distribution facilities. This pressure has fostered a reluctance from DISCOMs to promote rooftop solar to commercial and industrial sectors, which are key players from a revenue perspective. Within the TA component of the Grid-Connected Rooftop Solar Program, there has been collaboration with DISCOMs to create business models to minimize revenue losses as well as help DISCOMs understand the benefits of GRPV (e.g., how GRPV will help with management of the system, particularly during peak periods).

Limited debt financing: Due to previous exposure to the power sector, financial institutions are reluctant to provide debt financing to solar market actors including rooftop solar developers, installers, and aggregators. Moreover, MSMEs and residential consumers—currently the markets with the most potential for GRPV development—do not have the means to obtain adequate financing. The investment programs have reduced this reluctance by providing less risky conditions for lenders—e.g., via co-financing, RESCO ecosystem, and credit guarantee mechanisms for MSMEs.

Institutional/capacity barriers

Weak coordination: There is weak coordination between central and state government agencies, and between government agencies and relevant private stakeholders in the rooftop solar industry.

Lack of experienced GRPV installers: The rooftop solar industry in India is fragmented, with many installers involved due to the low barriers to entry, making it difficult for residential customers to find someone they can trust. Building the skills of GRPV installers is crucial. Current technical training programs lack field training, and awareness of the programs is poor among potential trainees and in the industry in general. Creating technical standards for the profession could also increase consumer trust.

Skills and knowledge gaps: Government actors and financial institutions do not have the capacity to provide continuous institutional and technical support (e.g., certification and enforcement of quality and technical standards) for scaling-up rooftop solar technologies. The technical assistance portion of the Grid-Connected Rooftop Solar Program has addressed this issue by improving the institutional capacity of the SBI, DISCOMs, State Nodal Agencies (SNAs) and State Electricity Regulatory Commissions (SERCs).

Social barriers

Lack of consumer awareness: Consumers are not aware of the costs and benefits or the financing options available for rooftop solar technologies. This is particularly true among residential consumers, who tend to perceive high upfront capital costs and have limited capacity to evaluate technical aspects of rooftop solar installations.

Limited access for women to the solar industry labor market: There are several barriers to women's participation in the solar industry in India, related to safety and security, societal norms, lack of flexibility, and underestimation of women's abilities.[47] The lack of safety at on-site solar projects as well as the lack of company policies to support women (such as paid maternity leave and sexual harassment policies) deter women from entering the field. Gender norms and biases further reduce women's access to opportunities.

Additional barriers

In order to successfully scale up solar park (transmission) technology, additional specific barriers will need to be addressed, including:

Transmission bottlenecks: Solar sites tend to be concentrated in certain states within India and certain regions within those states. This geographic concentration can lead to an unbalanced power system, where the energy supply is centralized in a few resource-rich areas and is not connected to areas where there is high energy demand. Furthermore, some states in India require renewable energy projects to only sell electricity to DISCOMs within the state.[48]

Coordinating solar park and transmission projects: Sufficient transmission infrastructure is key to ensure that solar power generated at solar parks is evacuated to the grid. However, while renewable energy projects can take 12–18 months, transmission infrastructure can take up to five years to complete. [49]

Providing access to hard-to-reach regions: As India increases its solar capacity, it will simultaneously need to make that energy more accessible to rural areas and encourage poorer states to adopt solar power technologies. In order to ensure/maintain affordability, it is important to assess the appropriate balance between increasing interconnection and increasing local generation assets in hard-to-reach regions.

Difficulties in acquiring land and insufficient infrastructure for solar park development: Some barriers which the Solar Park Transmission program addresses will remain an issue in other regions of the country including obtaining suitable land and promoting clearance for solar parks (transmission projects). Public sector investment in road access, security, permits, and land allocation will remain key factors in making solar park projects attractive for investors.[50]

Lack of coordination: There is a lack of coordination between state-level transmission planners and central planning agencies.[51] In a step towards addressing this, the Central Electricity Authority (CEA) has adopted an econometric forecasting model, which is to project long-term electricity demand scenarios until 2036.

Limitations on cost savings: Although increased investments in the transmission system lead to higher transmission charges, the restrictions on the generation and price constraints on coal plants restrict the cost savings.

Future Opportunities for Realizing DIs through Solar Power Technologies in India

The review of the Solar Park Transmission program and the Grid-Connected Rooftop Solar Program identified several opportunities for scaling up solar power technologies and further enhancing DIs:

Reaching new market segments to scale up solar rooftop technologies

Given India's high solar potential, there remains significant opportunities to scale up solar technologies, particularly solar rooftop, across the country. The National Institute of Solar Energy has estimated that India has about 748 GW of solar potential.[52] Two market segments that are currently underdeveloped (particularly for rooftop solar) are rural and suburban residential and MSMEs, because lenders are reluctant to provide debt financing. Notably, 16 percent of installed rooftop solar capacity comes from residential consumers.[53] The World Bank has provided guarantees to help lenders accept the risk. Incentivizing rooftop solar and raising awareness for these two groups using innovative business models (e.g., demand aggregation) could help with scaling up GPRV. The solarization of government buildings is also considered to have huge potential for the GPRV industry. Incentivizing rooftop solar, particularly in rural regions, will not only lead to greater market development (leading to local/regional economic benefits), but will also introduce more reliable electricity supply in remote areas. Further, the replacement of fossil-based electricity with solar power will reduce emissions and air pollution and ultimately lead to health benefits.

Replication of project's success in creating enabling conditions for rural electrification

As the share of variable renewable energy (VRE) increases in India, developing transmission infrastructure will become even more valuable. The Solar Park Transmission program gave the public and private sectors more confidence to initiate similar projects. There will be future opportunities in replicating the support provided by this program in poorer/weaker regions that are not yet involved.

The development of transmission lines in states where solar power development is at an advanced stage is attractive to private sector investors. The project could be replicated in other states, where a) solar power is at a more nascent stage; b) the state could benefit from solar power to drive further electrification benefits (i.e., where the local network is not sufficiently reliable to provide stable supply to all electrified villages); or c) states have lower VRE systems integration ranking. Further, the replacement of fossil-based electricity with solar power will reduce emissions and air pollution and ultimately lead to health benefits.

Variable renewables integration and de-risking private capital for new challenges

At the beginning of the Solar Park Transmission program*,* solar park transmission investments were unattractive to private sector investors, because rooftop solar projects were once considered risky and had high interest rates. By setting up financial schemes (e.g., RESCO ecosystems and credit guarantee mechanisms) and illustrating positive results from the solar technology investments, the CTF program has been successful at de-risking the market and making these types of projects competitive. Private sector investors are expected to continue playing an increasingly large role in the solar power market, but as India reaches a higher degree of reliance on variable renewables, additional investments will be required to ensure network integration. Both CTF and its partners will remain relevant in enabling actors to keep costs down for consumers as the grid moves to the higher system integration level. In this way, not only will investments lead to more reliable electricity supply but also affordable electricity. Furthermore, the replacement of fossil fuel-based electricity with solar power will reduce emissions and air pollution and ultimately lead to health benefits.

Integration of battery storage with on-site solar power

Incorporating on-site battery storage of solar power technologies is considered a next step in financing in the solar power market. On-site battery systems can play a key role in reducing demand in peak hours, reducing pressure on DISCOMs. It will be important for policy and regulatory barriers for batteries to be removed to encourage battery storage innovations.[54] Battery storage can also play a role in increasing the reliability of the electricity supply, further unlocking the DIs that result from increased/reliable access to electricity.

Support for regulatory developments to enhance power system flexibility

The establishment of power system flexibility will be important as renewables are scaled up. This flexibility includes demand-side flexibility, power plant flexibility, energy storage and grid flexibility, taking into account the regional and national context.[55] For instance, the agricultural sector can facilitate balancing energy supply and demand via involuntary irrigation load shifting. Time-of-use (ToU) tariffs are also an important element of enabling more demand-side flexibility. ToU tariffs are currently implemented by most Indian states for large industrial and commercial consumers, but ToU tariffs could be expanded to residential consumers and electric vehicle smart charging. Smart metering in the residential sector will be necessary to extend ToU tariffs effectively. These power system flexibility mechanisms are instrumental in increasing the reliability of the renewable electricity supply.

Making rooftop solar more system-friendly

A distributed solar registry available to DISCOMs would help improve DISCOMs' management of the power system. This registry would be publicly available and anonymized with mandated registration for all new installations. Further, to make rooftop solar a system-friendly resource, connection codes should include requirements for reactive power and voltage control capabilities. Improving DISCOMs' ability to support solar power integration is important for scaling up solar power and thus enhancing the DIs from solar projects.

Making the solar industry more accessible for women, with more gender-inclusive company policies

Even if companies in the solar industry want to hire women, there are not many applying for solar jobs. To attract women, gender-responsive training programs and company policies are needed. Targeted internships/mentorships could increase the number of qualified women training candidates, for instance. Providing training programs online would also make them more easily accessible. For jobs in the solar industry, it is important to ensure flexibility (i.e., maternity leave, flexible working hours) and safety (i.e., ensure safe access to project sites and enforce sexual harassment policies). Having more gender-balanced senior management is also important and would create female role models in the industry. Women's participation in the sector can also be encouraged through investments focused on gender equality, such as the IDB Invest's Gender Action Plans, which includes projects supporting women in science and technology fields and female-owned businesses.

Future Research

CIF and its partners should consider additional research to facilitate the analysis of additional DIs associated with grid-connected solar rooftop and solar park (transmission) technologies in India, including:

Employment opportunities from solar park transmission

Estimating direct job creation from transmission is difficult: this feedback has been provided by ADB and can be further inferred from the lack of estimates of job creation from transmission in the CEEW study on job creation in renewable energy in India. Moreover, indirect employment opportunities depend on many factors, including the environment of the project development area, the capacity of the developers, size of the project, policies, etc. According to the ADB stakeholders, it is unclear whether project developers and state-level government agencies understand the magnitude of job creation from these projects. Quantifying this impact would require additional field research.

Community and regional economic benefits

Community and regional economic benefits, in terms of economic growth, increased wages, improved labor conditions and gender equity in the solar power industry are also difficult to quantify. Doing so would require a more extensive analysis (including field research) and it is possible that the impact would be observed only in the long term.

Health benefits

Estimation of the resulting health benefits from air pollution reduction would require additional data collection and modeling.

Table 8: Interviewee List

Organization	Designation	Name
Asian Development Bank	Principal Energy Specialist	Jiwan Sharma Acharya
	Climate Finance (Energy) Specialist – Consultant	Karan Chouksey
	Senior Climate Change Specialist	Christian Ellermann
	Project Officer (India: Solar Transmission Sector Project)	Kazuhiro Horiguchi
	Climate Investment Funds Coordinator	Jemimah Jamolangue
World Bank	Senior Energy Specialist	Amit Jain
	Energy Consultant	Abhinav Goyal
IEA	Energy analyst (clean energy transitions)	Kartik Veerakumar
	Energy analyst	Pablo Hevia-Koch
	Energy analyst	Zoe Hungerford
CEEW	Program Lead	Neeraj Kuldeep
	Program Associate	Akanksha Tyagi

Endnotes

[1] Central Electricity Authority, *Installed Capacity*, December 2021, available at: https://cea.nic.in/installed-capacity-report/?lang=en
[2] International Energy Agency (IEA), *Total final consumption (TFC) by sector, India 1990–2019*, available at: https://www.iea.org/data-and-statistics/data-browser?country=INDIA&fuel=Energy%20consumption&indicator=TFCShareBySector
[3] Over the past two decades, electricity consumption per capita continuously increased until 2020, when electricity consumption per capita dropped below zero. This was due to Covid-19 lockdown restrictions in India, halting industrial and other economic activities. Aruga, K., Islam, M., & Jannat, A. (2020). Effects of COVID-19 on Indian energy consumption. Sustainability, 12(14), 5616.
[4] This includes 450 GW from variable renewable energy sources and 100 GW from hydropower.
[5] IEA (2021). *India Energy Outlook 2021*. International Energy Agency. https://www.iea.org/reports/india-energy-outlook-2021.
[6] Ministry of New and Renewable Energy, *Solar Energy*, 2021, available at: https://mnre.gov.in/solar/current-status.
[7] A solar park is a large-scale solar power generation station. Mega solar parks are solar power parks with a minimum of 500 MW capacity.
[8] Agrawal, S., Mani, S., Jain, A., Ganesan, K., State of Electricity Access in India, 2020, available at: https://www.ceew.in/publications/state-electricity-access-india#:~:text=96.7%20per%20cent%20of%20Indian,Pradesh%2C%20Rajasthan%2C%20and%20Bihar.
[9] IEA (2021). *India Energy Outlook 2021*.
[10] Agrawal et al., 2020. State of Electricity Access in India.
[11] Asian Development Bank (ADB), *Proposed Loan and Administration of Loan Power Grid Corporation of India Limited India: Solar Transmission Sector Project Guaranteed by India*, 2016, available at: https://www.climateinvestmentfunds.org/sites/cif_enc/files/meeting-documents/rrp_ind_solar_transmission_0.pdf
[12] IEA (2021). *Renewables Integration in India*. International Energy Agency. https://iea.blob.core.windows.net/assets/7b6bf9e6-4d69-466c-8069-bdd26b3e9ed1/RenewablesIntegrationinIndia2021.pdf.
[13] Ibid.
[14] Implementing Multilateral Development Bank
[15] Climate Investment Funds (CIF), *India*, n.d., available at: https://www.climateinvestmentfunds.org/country/india
[16] See World Bank data for CO_2 emissions (kt), 2020: https://data.worldbank.org/indicator/EN.ATM.CO2E.KT.
[17] See IEA data for CO_2 emissions by sector, India 1990–2019: https://www.iea.org/data-and-statistics/data-browser?country=INDIA&fuel=CO2%20emissions&indicator=CO2BySector.

[18] Reductions in local air pollution are difficult to attribute to a specific project, as a fossil fuel plant is not generally being replaced by a renewable energy project in the same location. Rooftop solar can, however, have a direct impact on air pollutant concentrations in the project's location.
[19] The transmission construction was completed and the ADB loan was closed, but updates to the existing facility have been ongoing as of December 2021.
[20] The funding for these new subprojects did not come from the CTF loan.
[21] ADB, *Amendment to the Loan Agreement for Loan 3521-IND: Solar Transmission Sector Project*, 2020, available at: https://www.adb.org/sites/default/files/project-documents/49214/49214-002-lna-en.pdf
[22] According to an interview with the ADB and the literature, new employment opportunities from transmission construction projects are difficult to estimate.
[23] This indirect mobilization assumes that the World Bank program kick-started the market as it provided concessional financing and supported the creation of an enabling environment through the technical assistance program. The rooftop solar capacity in the country increased from 500 MW in 2016, when the World Bank program was launched, to today's 6500 MW thanks to mobilized private capital. The estimate of $4 billion corresponds to the incremental increase in capacity at an average capital cost of $650,000 per MW for the 6000 MW capacity.
[24] The ADB project documents use this value to estimate the amount of avoided coal consumption.
[25] Cobenefits Study, *Future skills and job creation with renewable energy in India*, October 2019, available at: https://www.ceew.in/sites/default/files/CEEW-%20COBENEFITS-Study-India-Employment%2031Jan20.pdf
[26] This report used data collected from official sources to calculate employment coefficients as FTE jobs/MW/year, which normalizes employment variations during the construction phase. Rooftop solar is more labor intensive than ground mounted solar (solar park installations). Cobenefits Study, *Future skills and job creation with renewable energy in India*, October 2019, available at: https://www.ceew.in/sites/default/files/CEEW-%20COBENEFITS-Study-India-Employment%2031Jan20.pdf
[27] Power generation estimates are based on installed capacity and capacity factors from project documents. Note that these estimates do not account for degradation of installments and actual values may be slightly lower.
[28] World Bank, *Measuring the Results of World Bank Lending in the Energy Sector* ,2014, Available at: https://www.openknowledge.worldbank.org/bitstream/handle/10986/17370/853760BRI0ADD00for0collection0title.pdf?sequence=1
[29] This calculation assumes a 10% transmission and distribution loss, 35% residential energy use and 1,000 kWh of energy consumption per capita (based on GoI targets).
[30] The average number of household members in India is 4.8.
[31] This estimate is based on an average CUF of 16.6 and an assumed annual plant degradation factor of 1%.
[32] This was not found in the project documents. In the interview, ADB informed us that they did not have these figures yet but would have them once the project completion report was written.
[33] CTF, *CTF 2021 Results Report*, 2021, available at: https://www.climateinvestmentfunds.org/sites/cif_enc/files/meeting-documents/ctf_tfc.26_3.1_ctf_results_report_final_1.pdf
[34] This estimate is based on an average CUF of 16.6 and assumes an annual plant degradation factor of 1% and a CO_2 emissions factor of 0.79 tCO_2/MWh.
[35] World Bank, *Cover Page for CTF Project/Program Approval Request: Proposed Loan Power Grid Corporation of India Limited Solar Power Transmission Sector Project Guaranteed by India*, n.d., available at: https://pubdocs.worldbank.org/en/350061531505305681/1843-XCTFIN228A-India-Cover-Page-and-Project-Document.pdf
[36] Ricke, K., Drouet, L., Caldeira, K., & Tavoni, M. (2018). *Country-level social cost of carbon*. Nature Climate Change, *8*(10), 895-900. Available at: https://re.public.polimi.it/retrieve/handle/11311/1099986/420663/CountrySCC_v300718-preprint.pdf
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6. Indonesia Deep-Dive Case Study: Economy-Wide Impacts of Expanding Geothermal Power Generation

Project Details	Funding
Name: Geothermal Clean Energy Investment Project (GCEIP); Geothermal Energy Upstream Development Project (GEUDP); Geothermal Resource Risk Mitigation Project (GREM); Geothermal Power Generation Project (GPGP) **Country:** Indonesia **CIF Program Area:** CTF **Bank approval:**[1] July 2011 (GCEIP) **Effective since:**[1] May 2012 (GCEIP) **Expected closing:**[2] October 2029 (GREM) **MDB:** World Bank (GCEIP, GEUDP, GREM); Asian Development Bank (GPGP)	**Total Value:**[3] $4,454.6 million **CIF:** $483.25 million **Co-financing:** $3,971.35 million ($1,122.5 million is MDB co-financing) **Instrument type:** Loan, grant **Sector:** Public
Notes: (1) CIF approved the country Investment Plan in March 2010. "Bank approval" and "effective since" use the dates listed for the first project GCEIP. (2) "Expected closing" uses the closing date for the last project GREM. (3) Funding values include all CIF-supported geothermal projects in Indonesia, four of which are the primary focus of this case study (in sites including Ulubelu in South Sumatra; Lahendong in North Sulawesi; Wae Sano in East Nusa Tenggara; several sites in Eastern Indonesia; Dieng, Central Java; and Patuha, West Java).	

Key Highlights

- For more than a decade, CIF investments have supported geothermal energy development in Indonesia through upstream (de-risking exploration and drilling) and downstream (geothermal project development) projects.
- CIF's $483.25 million for Indonesia's geothermal development brought in $3.97 billion in co-financing and will mobilize additional commercial capital.
- Concessional finance provided by CIF lowered the cost of capital and helped make the projects competitive. MDB and CTF funds also helped to provide financial certainty and market confidence.
- Actual and forward-looking geothermal capacity expansion in Indonesia supported by CIF amounts to 1,815 MW, of which at least 320 MW were completed at the time of writing.

Topline Findings on Development Impacts

- **Geothermal market development:** Through geothermal investment funded by CIF, North Sulawesi exceeded Indonesia's national target of 23 percent renewable energy capacity nationwide by 2025. In addition, the project significantly reduced systemic power shortages and regular blackouts that previously plagued the region.

- **Job creation:** The geothermal projects supported by CIF directly created or will create an estimated 4,350 long-term jobs, and indirectly support more than 27,000 jobs. Most of these jobs are during the construction phase of development, although some are operational jobs.
- **Economy-wide impacts:** The geothermal projects supported by CIF have economy-wide impacts estimated at $107 million per year.
- **Education and human capital:** Expanded access to electrification, and more reliable electricity, facilitates increased access to education, and increased human capital valued at approximately $27 billion.
- **Health benefits:** Reducing reliance on fossil fuels for electricity generation, including diesel generators for backup power, produces health benefits of over $2 billion.
- **Other DIs:** Additional benefits of geothermal market development include local economic development and development of local supply chains, increased government revenues, improved access to public services and infrastructure, and capacity building benefits including improved local government coordination, and improved policy and regulatory environment.

Climate Investment Context and Overview

Indonesia's economy has grown significantly since the early 2000s. In recent years, the country's GDP has grown at an annual rate of around 5 percent, with a slowdown to 4 percent GDP growth in 2021 after a major drop in 2020 due to COVID-19.[1] GDP growth projections through 2030 remain high, at 5–6 percent per year.

While this economic growth led to a substantial improvement in living standards for a large and diverse population, the country still faces significant income inequality. Major development challenges remain for poorer households, typically situated in remote areas and islands.[2] While the poverty rate as a share of the Indonesian population declined to about 9 percent over the last decade, the effects of COVID-19 confound efforts to lift 26 million people—and possibly 10 million more due to the pandemic—out of poverty.[3]

Power demand growth of 4.9 percent is expected to coincide with the projected economic growth. The Government of Indonesia (GoI) aims to meet this demand while reducing 29 percent of the country's greenhouse gas (GHG) emissions by 2030. The country has committed to accelerate the clean energy transition by increasing the share of renewable energy in the country's electricity's mix to 23 percent by 2025 and 31 percent by 2030; for new energy capacity additions, the target is 51 percent renewables by 2030.[4]

Table 1 shows the amount of geothermal, hydro, and solar foreseen to reach the 2030 renewable energy target. The GoI and the state utility Perusahaan Listrik Negara (PLN) aim to utilize the country's major geothermal energy potential—the highest in the world, estimated at 29 GW, or 40 percent of the world's total resources. So far, 2 GW of geothermal energy have been developed, and more than 3 GW in capacity additions are planned for this decade. Based on the Supply Plan, geothermal energy would represent about 5 percent of the intended total—about 100 GW of power generation capacity in 2030.

Table 13. Indonesia's 2021–2030 Electricity Supply Plan

New and Renewable Energy	New Capacity (MW)										
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
Geothermal	136	108	190	141	870	290	123	450	240	808	**3,355**
Hydro	544	207	409	376	2,627	370	456	1,611	1,778	1,950	**10,390**
Solar	60	287	1,038	624	1,631	127	148	165	172	157	**4,680**
Wind		2	33	337	155	70					**597**
Biomass/waste	12	43	88	191	221	20		15			**590**
Other						100	265	215	280	450	**1,310**

Adapted from Ashurst (2021): PLN's New Green(er) Electricity Supply Business Plan – Key Highlights

Purpose and Scope of the Case Study

This case study evaluates the development impacts (DIs) of climate finance for geothermal energy expansion in Indonesia. The case study results are intended to help strengthen CIF's programmatic approach to supporting geothermal energy, while offering lessons that can help maximize DIs pertaining to the energy transition in Indonesia and other developing economies.

For more than a decade, the World Bank and CIF have actively supported geothermal energy development in Indonesia. World Bank projects have supported both the downstream development phase—i.e., the more advanced stages resulting in constructing geothermal plants—and the upstream phase, focused on de-risking initial exploration and drilling. The rationale for this dual approach is to improve the downstream business case for geothermal energy while providing financial mechanisms, technical assistance, and regulatory advice to reduce uncertainties and investment risks.

In 2010, CIF's Clean Technology Fund (CTF) approved a Country Investment Plan submitted by the GoI, which has been periodically updated, and currently provides US$483.25 million of direct CIF financing for geothermal energy development in Indonesia, supported by almost $4 billion in co-financing.[5] This case study focuses closely on four projects that are located in Ulubelu in South Sumatra, Lahendong in North Sulawesi, Wae Sano in East Nusa Tenggara, several sites in Eastern Indonesia, Dieng, Central Java, and Patuha, West Java. These projects are listed below and shown in Figure 1, labeled with their location, project name, and the geothermal developer:[6]

- The **Geothermal Clean Energy Investment Project** (**GCEIP**—$125 million in CIF funding; 150 MW) with geothermal plants in Ulubelu (110 MW, South Sumatra) and Lahendong (40 MW, North Sulawesi), completed in 2018.
- The **Geothermal Energy Upstream Development Project** (**GEUDP**—$49 million in CIF funding; 65 MW) with four projects to be developed by 2025, of which Wae Sano in East Nusa Tenggara is most advanced.
- The **Geothermal Resource Risk Mitigation Project** (**GREM**—$75 million in CIF funding; 1 GW), which aims to support about 10 projects across different locations, mostly in Eastern Indonesia, by 2029.

- The **Geothermal Power Generation Project** (**GPGP**—$35 million in CIF funding; 110 MW), with two geothermal plants to be developed by 2024 in Dieng, Central Java and Patuha, West Java.

The remaining projects were not a focus of the qualitative data collection and analysis for this case study, as they were not mature enough to document DIs.[7] However, all projects are included in the computable general equilibrium (CGE) analysis.[8]

Figure 5. Map of CIF Geothermal Project Areas in Indonesia

Source: Evaluation team based on map of Indonesia and case study data.

The characteristics of the geothermal projects in Indonesia are presented in Table 2. In total, Total CIF funding is $483.25 million, with an expected installed capacity of 1,815 MW.

Table 2. Characteristics of Geothermal Projects

Project Name	MDB Partner	Focus of Case Study Research?	Included in the CGE Analysis?	Total CIF Funding (million USD)	Installed Capacity (MW)
Geothermal Clean Energy Investment Project (GCEIP)	World Bank	Yes	Yes	$125	150
Geothermal Energy Upstream Development Project (GEUDP)	World Bank	Yes	Yes	$49	65
Geothermal Resource Risk Mitigation (GREM)	World Bank	Yes	Yes	$75	1,000
Geothermal Power Generation Program (GPGP)	ADB	Yes	Yes	$35	110
Private Sector Geothermal Project (PSGP)	ADB	No	Yes	$199.25	490
Total				**$483.25**	**1,815**

Development Impact Pathways and Case Study Focus

The main objectives of the geothermal projects are to: (i) increase power generation from renewable geothermal resources; (ii) reduce global and local negative environmental impacts; and (iii) facilitate investments in geothermal projects, with the GEUDP and GREM projects focusing on Eastern Indonesia, where energy access is relatively low. The projects also contribute to a range of DIs that are driven by downstream and upstream interventions.

The investments have economic, market development, social, and capacity-building impacts. Financial support from CIF contributes to the pool of fiscal support channeled through the Indonesian Ministry of Finance (MoF), which in turn accelerates green economic growth in Indonesia, and provides economic benefits including new local jobs and business opportunities. Financing is also key for shifting market dynamics and enabling geothermal development. The attractiveness of geothermal energy as an investment also depends on institutional dynamics, including key stakeholders' ability to facilitate market development and a supportive regulatory environment. Lastly, the intervention can also contribute to social impacts, including community wellbeing and other social impacts.

The pathways for realizing these DIs are shown in Figure 2, which includes benefits from both upstream and downstream development phases. Activities are common in both phases, with fiscal/regulatory support having a relatively larger weight upstream and technical support having a relatively larger weight downstream. Development impacts are mostly unlocked downstream, while upstream, the enabling environment and social impact take precedence.

The **dark blue boxes** indicate the DIs quantitatively assessed in the case study: geothermal energy production, increased electricity reliability, reduced fossil fuel generation, health benefits, direct employment opportunities, and economy-wide benefits including job creation, value add, and human capital development. The **light blue boxes** indicate DIs qualitatively assessed in this case study: capacity building; local economic development/supply chain development; geothermal market development; access to essential services; government income; improved livelihoods and wealth; and gender benefits. Some of these DIs are inherently qualitative (e.g., capacity building); information was not available to quantify others.

Figure 2. Impact Pathways for Geothermal Energy Development

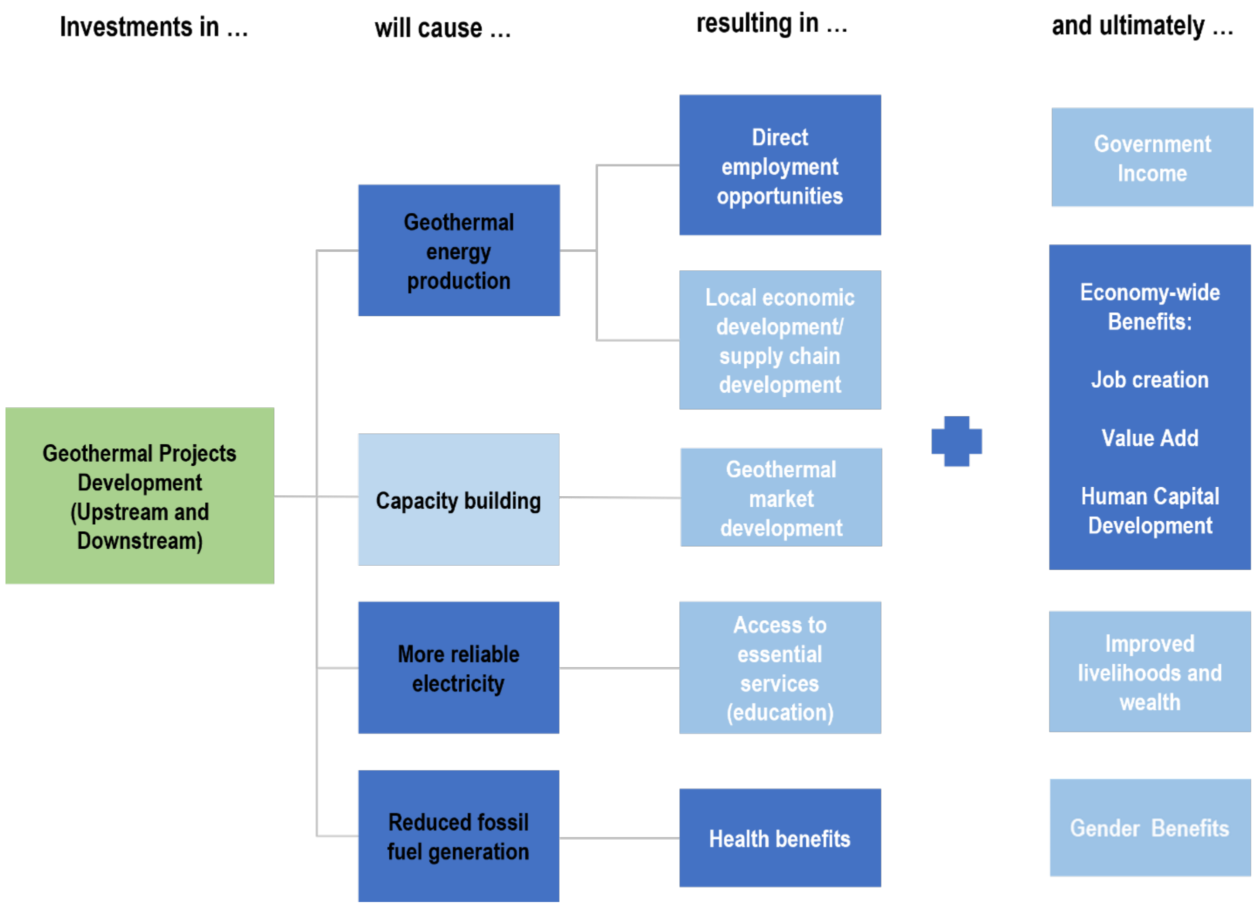


Table 3 shows whether the DIs are noted in project documents as potential outcomes and/or are activity tracked and measured.

Table 3. Geothermal Energy Expansion DIs

DI	In Project Documents?	Tracked by Project?
Economic DIs		
Geothermal energy production	YES	YES
Increased electricity reliability	NO	NO
Increased labor productivity (from increased electricity reliability)	NO	NO
Direct employment	YES	YES
Indirect employment	YES	YES
Local economic development	NO	NO
Government income (tax revenue)	NO	NO
Increased economic output	YES	YES

DI	In Project Documents?	Tracked by Project?
Social DIs		
Health benefits from reduced air pollution	YES	YES
Improved access to public services and infrastructure	YES	NO
Improved livelihoods and wealth	YES	YES
Gender benefits	YES	YES
Education and awareness	NO	NO
Markets/Institutional DIs		
Geothermal market development	NO	NO
Market facilitation	YES	YES
Policy progress and regulatory facilitation	YES	YES
Local institutional coordination	NO	NO
Improved skills and processes	YES	YES

Table 4 shows the roles of a few key stakeholders. PLN plays a key role together with the Indonesian Ministry of Energy and Mineral Resources (MEMR) and the MoF. The MEMR controls the regulatory framework, while the power purchase agreements (PPAs) are overseen by the PLN. The MoF provides fiscal support and takes an active role in implementing geothermal projects together with geothermal developers. In 2009, the MEMR introduced a commercial tariff in geothermal PPAs (MEMR Regulation No 32/2009), with the MoF subsequently developing funding mechanisms while undertaking cross-ministry geothermal collaboration with MEMR. With the introduction of a new tariff system in 2014 (MEMR Regulation no 17/2014), geothermal development suffered a setback as the system favors more competitively priced fossil fuels at the expense of geothermal energy.[9] The MEMR has issued new Regulations on the Purchase Price of Electricity from Renewable Energy in September 2022 (Presidential regulation No 112/2022), which will hopefully remedy the setback by creating a tariff system to accelerate geothermal development.

Table 4. Key Stakeholders and Roles

Stakeholders	Roles
Ministry of Energy and Mineral Resources (MEMR)	Energy market regulator
Ministry of Finance (MoF)	GoI's focal point for CTF and regulator for fiscal support for geothermal development
Perusahaan Listrik Negara (PLN)	State-owned utility / grid operator
Pertamina Geothermal Energy (PGE)	State-owned developer in the GCEIP
Geo Dipa Energi	State-owned developer in the GEUDP and GPGP
Local governments	Local facilitator / community governance

This case study uses data from document review, interviews, and site visits. World Bank documents provided a draft theory of change, activities, and, for the downstream GCEIP project completed in 2019, actual results. Geo Dipa Energi, the developer for GEUDP and GPGP, shared documents on the impact of CIF funds for the project, which helped us to map and quantify several impact indicators. The document review helped to inform primary data collection. We conducted a total of 21 interviews with key stakeholders. An extensive site visit was made to North Sulawesi in the Lahendong area to capture insights from the key developer, the main local governmental agencies, as well as other community beneficiaries and local businesses. Sub-Appendix 6A provides further details about the data sources and interviews.

In addition to qualitative data collection and analysis, we used a computable general equilibrium (CGE) model to estimate economic benefits, emission reductions, and job creation from geothermal expansion in Indonesia. The modeled economic benefits arise from increased electrification, increased access to education and the resulting increase in productivity, and health impacts from reduced air pollution. Further details are provided in Sub-Appendix 6B.

Development Impacts from Expanding Geothermal Power Generation

The selection of DIs is based on the development objectives of the geothermal projects, and the indicative and actual results. Based on data availability and importance of the DIs identified, we categorized four types of impacts: market development, economic, social, and capacity building.

Geothermal market development

A key reason for the capital mobilization is to reach the target of renewable energy share in the electricity mix of 23 percent by 2025, implicitly altering the competitiveness of renewables—here, geothermal—in relation to fossil fuels. Nationally, this will make the Indonesian economy less reliant on imported petroleum products and thereby improve energy security, while accelerating emission reductions, creating institutional capacity for sustainable development, and placing governmental actors in a better position to achieve climate and energy targets.

The target of 23 percent renewable energy capacity nationwide by 2025 was exceeded on the local level with the development of geothermal energy in North Sulawesi, where geothermal accounted for the largest share of the electricity mix in 2021. In this region, renewable generation now totals 30 percent, and 28 percent of all power is from the Lahendong geothermal fields, significantly reducing systemic power shortage and regular blackouts for cities and regencies.[10] This success reflects a serious commitment and collaboration among high-level local government agencies and key stakeholders at all levels that facilitated local geothermal development. Furthermore, the Lahendong geothermal field under the GCEIP has provided a stable power supply, with a capacity factor of 90 percent in the North Sulawesi power grid; according to the project developer, this demonstrates the transformational impact of geothermal projects.[11] Finally, development of the Lahendong 5 and 6 fields contributed to closing a power supply deficit of 20 MW, which was previously met by diesel generation, which is quite polluting, and unreliable small hydropower.

Economic impacts

Geothermal expansion provides green economic growth driven by investments from CIF, co-financiers, and private capital markets. Geothermal projects contribute to local and regional economic development, supporting increased productivity and job creation. This also leads to the collection of government income from tax revenue. In this case study we took two approaches to estimating economic impacts: first, from direct project reporting and interviews, and second, using CGE economic modeling.

1) Direct project data estimated impacts

Direct job creation in geothermal energy

Most direct employment impacts from geothermal development occur during the construction and operation phases, rather than the upstream exploration phase. The GCEIP employed 4,800 workers across the 40 MW Lahendong sites 5 and 6 (1,800 workers) and the 110 MW Ulubelu sites 3 and 4 (3,000 workers). In comparison, one of the four expected GEUDP (65 MW) exploration sites, Wae Sano, is predicted to absorb 161 workers for exploration and 860 workers for subsequent development stages.[12] For the GPGP and Dieng Unit 2 (55 MW), Geo Dipa Energi expects to employ 1,340 workers across: (i) preparation works (35); (ii) drilling (200); (iii) civil works, engineering, procurement, and construction (1,000); and (iv) operations (105).[13] The second and third work categories (drilling, and civil works, reengineering, procurement, and construction) will employ the majority of local workers estimated at around 240 people. Geo Dipa Energi has developed an action plan that integrates gender and vulnerable communities in recruitment processes, elaborated further in the social impacts section.

Local economic development

The emergence of geothermal energy in North Sulawesi has led to considerable growth in local income via local supply chains. The GCEIP project absorbed a variety of local workers with geothermal industrial development, cultivating a growth of local vendors and service providers to take up the core and supporting geothermal activities.[14] The increase in competent local suppliers and service providers has led to locally anchored engineering work (e.g., piping). PGE has worked with more than 120 local vendors or service providers in North Sulawesi. Local communities also benefited from business opportunities such as selling food for workers and providing temporary accommodation. In the GCEIP, 41 percent of the World Bank and CTF funds went to domestic firms/organizations; this includes $123 million paid to PT Rekayasa Industri, an Indonesian state-owned enterprise.

The construction phase was the most labor intensive, both in terms of direct and indirect local employment. In direct employment terms, more than 50 percent of staff required for the development of the Lahendong plants came from North Sulawesi. However, local workers typically lacked the skills required for exploration and the post-construction operations of the geothermal plants. Indirect employment was primarily in the form of maintenance and technical services as well as civil works at the plants, the latter of which includes laundry and catering services. Indirect employment was also created through restaurants and resorts, which employed around 100 village community members in Lahendong (Linow Lake) under the GCEIP.

Government income

The province in which the energy is produced, the regencies in which each project is located, and nearby regencies all financially benefit from the allocation of untaxed state revenue received by the state-owned geothermal developers under the GCEIP. The local government also receives a geothermal production bonus from the sale of geothermal energy equal to 0.5 percent of the gross income generated from the sale of electricity. These sources of income are significant, with the geothermal production bonus accounting for the highest additional income category.

During the COVID-19 pandemic, the income from the production bonus for Minahasa regency in North Sulawesi was a key funding source for social donations, medical equipment, masks, and other necessities. Stakeholders stated the production bonus can help maintain the continuity of geothermal production by fostering a mutually beneficial relationship between the developers and the regional government.

2) CGE Modeled Economic Impacts

We model DIs at two levels:

- First, we model benefits at a national level, based on expected geothermal expansion in Indonesia. Specifically, the modeling examines impacts based on the share of geothermal power added to the electricity mix in 2030 and 2045, ranging from 1 to 15 percent, and different geothermal levelized cost settings ranging from $25/MWh to $100/MWh. In the main body of this case study, we present the impact of adding 5 percent of geothermal energy in the electricity mix in 2030.[15] Indonesia's 2021–2030 Electricity Supply Plan is broadly in line with our central scenario as it expects the share of geothermal within the mix to be 5 percent by 2030. Sub-Appendix 6B presents the full range of analytical results. This analysis estimates the impacts of geothermal investments at a national scale. We use these results to interpolate the impacts for the CIF-funded projects.
- Second, we model benefits at the projects/case study level, examining the estimated impacts of the specific projects funded by CIF. Table 5 summarizes CGE outputs for the 2,120 MW of installed capacity for the geothermal projects funded by CIF.[16] This includes formal direct and indirect employment (29,001 jobs), annual GHG emissions reductions (1.3 million tCO_2e), and economy-wide impacts ($107 million annually for the estimated 30-year lifetime of the geothermal assets).[17] Importantly, these results depend on the projects being installed as planned. This will require overcoming persisting barriers to geothermal development (see Drivers and Barriers that Affect Results). We explain these results in greater detail below.

Table 5. CGE Outputs for 2,120 MW of Geothermal Projects in Indonesia

Formal Employment (# Jobs)	GHG Emission Reductions (tCO_2e)	Economy-Wide Impacts without Additional Benefits, $M/yr
29,001	1,332,344	107
Note: Results assume a levelized cost of electricity for geothermal of $25/MWh. At $50/MWh, the economy-wide impacts of the projects are negative relative to the cheapest alternative source.		

Output and productivity

The combined economic impact of adding 5 percent of geothermal energy in the electricity mix by 2030 would increase Indonesia's GDP by 3–4 percent relative to a baseline scenario without geothermal power. This economic benefit is mostly driven by increased electrification, with additional benefits coming from education, improved respiratory health, and employment. Increased electrification alone leads to estimated economic benefits of $64 billion in GDP relative to the reference scenario. This assumes that all added geothermal capacity is used for increased electrification, providing increased energy access and, in turn, improving human capital in Indonesia.

For the 2,120 MW of geothermal capacity supported by the CIF-funded projects, the economy-wide impacts are $107 million per year. Based on the CGE results, we also monetize the health and electrification benefits of the CIF-funded projects over a 30-year period, which are $2.2 billion and $27.6 billion, respectively. These benefits are discussed in more detail under social impacts.

Indirect job creation

National CGE modeling results indicate the creation of more than 10,000 formal sustained long-term jobs from adding 5 percent geothermal to the Indonesian electricity mix. The model estimates the employment needed for the operation phase and construction phase of geothermal development as well as sustained long-term jobs. Direct jobs created from planned geothermal energy capacity additions towards 2030 can reach 3,800 in the operational phase, 64,600 in the construction phase (during two years of construction), and 6,460 long-term construction jobs.

Applying the modeled economic benefits only to the CIF-supported geothermal projects, the addition of 2,120 MW of CIF-backed geothermal capacity is estimated to create 1,611 jobs in the operation of the power plants, 27,390 jobs in the construction phase (during two years of construction), and 2,739 long-term jobs in the geothermal construction sector.

Employment created from geothermal projects does not account for local jobs resulting from improved power reliability, energy access, or arising in other indirect ways. For example, the byproduct waste heat from the Lahendong geothermal plants enhanced—by a factor of five—the productivity of a sugar factory run locally by the Masarang Foundation, due to a more stable energy supply.[18] The increased reliability and productivity from geothermal energy translated into higher incomes for the local farmers. Moreover, these operations run on a commercial scale as the sugar products are mostly exported or distributed to the small-scale food and beverage industry.

The tourism industry was also empowered by clean energy reliability and access, helping the sector to create jobs and wealth for local communities. This benefit is exemplified by tourist attraction Danau Linow Resort at the Linow Lake in the Lahendong area (North Sulawesi), where geothermal energy has contributed to indirect job creation for local community members—a total of 100.[19] Separately, the village of Wae Sano on Flores Island has been formally declared as a village with high tourism potential, where geothermal energy will play a key role to promote the area for sustainable tourism.[20] This shows how CIF-backed geothermal energy development can be of strategic interest in the local economic development of communities as they position themselves to absorb workers and attract tourists.

Social impacts

Social impacts of geothermal projects include health benefits, energy access, enhancement of public services and infrastructure, shared prosperity, educational benefits, and gender equality.

The CGE model monetizes the health and electrification benefits of the CIF-funded projects over a 30-year period, which are $2.2 billion and $27.6 billion, respectively, as shown in Table 6. These are discussed below, along with other social impacts that are addressed qualitatively.

Table 6. CGE Outputs for 2,120 MW of Geothermal Projects in Indonesia

Additional Impacts of the Project	
Health Benefits, (million USD)	Human Capital if Project Provides Access to Electrification (million USD)
2,204	27,574
Note: Results assume a levelized cost of electricity for geothermal of $25/MWh. At $50/MWh, the economy-wide impacts of the projects are negative relative to the cheapest alternative source.	

Reliable access to energy

Based on CGE modeling, the increased access to energy is further expected to lead to an educational rate of return, increasing labor productivity by 12 percent. Under the scenario in which 5 percent of geothermal energy is added in the electricity mix in 2030, the benefits of increased human capital from access to reliable electricity are valued at about $68 billion. The increase in labor productivity adds $4 billion by 2030, on top of the economic benefits from increased electrification itself. Applying the modeled benefits only to the CIF-supported geothermal projects, human capital benefits are $27.6 billion over the estimated 30-year life of the assets. Labor benefits from the higher rate of return to education are in addition to human capital benefits due to access to reliable electricity. For the CIF-supported projects, human capital benefits are $27.6 billion and labor productivity benefits add another $1.3 billion for a total of $28.9 billion.

The expansion of local power grids as part of the GEUDP (65 MW) will extend energy access to 116,411 households or 582,000 individuals by 2025. The GREM project aims to establish 1 GW of geothermal energy by 2029. These power grids are situated in remote marginalized communities in Eastern Indonesia and serve a significant number of vulnerable communities.

In contrast to the above projects, the GCEIP did not intend to increase electrification; however, it did help to close a supply deficit of 20 MW in Lahendong and ensure a more reliable electricity supply, which supports productivity, convenience, and safety. The closing of the 20 MW supply deficit also contributed to the displacement of polluting diesel generators and small hydropower.

Health benefits from reduced air pollution

By avoiding emissions from fossil fuels, including coals as a primary fuel and diesel (which is widely used for backup power), geothermal energy offers substantial health benefits, which are estimated to equal 8 cents for each kWh of geothermal electricity. This translates into roughly $5 billion in economic benefits from adding 5 percent of geothermal in the electricity mix in 2030, or $2.2 billion in economic benefits from only the CIF-funded projects, reflecting the value of reducing premature mortality that arises from exposure to air pollutants.

From the GCEIP alone, the health benefits of avoided local pollutants amount to $156 million, due to the avoided coal emissions estimated from both Ulubelu 3 and 4 (110 MW) and Lahendong 5 and 6 (40

MW). Furthermore, the Minahasa Local Agency for Environment in the Lahendong area finds the air quality in communities surrounding the geothermal plants to be acceptable, below the maximum levels allowed for each local pollutant; this would be highly unlikely for a similarly scaled coal plant.[21]

Access to public services and infrastructure

The increase in geothermal capacity and power reliability has led to improved quality of public services. In North Sulawesi, local governments, businesses, and citizens now experience fewer power shortages and no more regular blackouts in cities and regencies. Government income from the geothermal production bonus also helped mitigate problems from COVID-19, by providing social donations and protective medical equipment. Health impacts through public services are evident from the effect of a 24-hour power supply, optimizing the functional activities of a local health center in the Minahasa Regency, and enabling more regularly conducted health programs for newborns and small children.

The GCEIP has also led to improved local infrastructure. In relation to geothermal development, access roads have been built and further extended to connect farmers and villagers, improving their mobility. Income from the geothermal production bonus has also supported the development and maintenance of infrastructure in the Minahasa and Tompaso regencies, which now have high-quality roads.

Improved livelihoods and wealth

The completed GCEIP provides an indication of how the geothermal development process can facilitate shared prosperity and increased productivity. As described in the economic impacts section, the existence of geothermal energy projects leads directly and indirectly to new or sustained jobs and community development through education and work-related skills through training programs. Directly, growing local geothermal supply chains in North Sulawesi offered new job opportunities with higher income than more traditional work such as farming. Indirect job opportunities also emerged in production and service sectors such as farming, restaurants, and resorts.

Gender-related benefits

Geo Dipa Energi's implementation of environmental and social plans in the GPGP showcases gender-balanced human resource management. Geo Dipa Energi established a recruitment committee supporting the inclusion of women as part of its Gender Action Plan. During the construction and commissioning of geothermal plants, the share of women was 19 percent (the target was 20 percent), and the company is on track to have women make up 27 percent of the committee for the Grievance Redress Mechanism,[22] as well as to increase the share of women among new hires to 18 percent (16 percent of existing staff were women in 2019). From 2022, the proportion of women in training programs—including, for example, engineering practices and contract management—will increase from 20 to 30 percent, and gender-sensitive designs will be promoted in community plans and stakeholder consultations. Overall, the integration of Gender Action Plans in the GREM project is supported by the World Bank explicitly targeting gender benefits.

Education and awareness

The economic impact of increased education from energy access is presented above. In addition, it should be noted that some of the public funding through the geothermal production bonus is spent on the local education system. Education is also supported through the CSR activities of developers as described below.

Geo Dipa Energi further suggests that the presence of the GEUDP and the CIF support helps to raise awareness around climate change. Geo Dipa Energi indicates that the presence of their geothermal project exploration can induce sustainable local actions and a low-carbon lifestyle, which will contribute to climate change mitigation and adaptation.[23] Examples of this might include emphasizing the clean energy narrative and involving village residents in areas such as energy-saving behavior, green transportation, waste management, tree planting, and land and forest fire control.

Corporate social responsibility

Several social impacts have resulted from geothermal developers' corporate social responsibility (CSR) activities.

Infrastructure: PGE extended the village road access in the Lahendong area for two local farms situated in different villages, and it is also helping install streetlights in the Tompaso subregency. In Central Java as part of the GPGP, Geo Dipa Energi will optimize the water distribution system from existing wells and conduct a feasibility study to improve the drinking water supply system for six affected villages around Dieng. Geo Dipa Energi will also assist one village in the rehabilitation of a 12-kilometer piping system from a water source on Mount Prau.

Education: PGE supports early childhood education in Lahendong and provides scholarships and teaching tools to elementary and junior high school students. PGE also partnered with university students in North Sulawesi to effectively support a local pig farming business in installing solar energy while transferring knowledge and experience to the participating students.

Health: Geo Dipa Energi has, through the GPGP, provided logistical assistance for the delivery of foods and immune boosting supplements during the pandemic and provided medical equipment such as masks, thermometers, and hand sanitizers. They also held COVID-19 vaccination clinics in August and September 2021 with a total of 250 participants. The PGE project in Lahendong provided similar COVID-19 health benefits and, through CSR activities, provided financial support to a private health clinic in Tondangow Village.

Community development: Several geothermal development areas hold great potential for tourism, as evidenced by the designation of Wae Sano as a tourism village. The community will directly benefit from enhanced energy access through geothermal, and indirectly from Geo Dipa Energi's social investments in tourism. Emerging from the geothermal development is also social investment to support the creation of an export village under GEUDP in collaboration with the Ministry of Village, Development of Disadvantaged Regions, and Transmigration. Beyond tourism, PGE has provided financial support to a local group of women providing sewing goods, while Geo Dipa will support a project on integrated farming. The case study also highlights that community development activities should account for issues and concerns raised by the local community during geothermal exploration and production.[24]

Capacity building

Market-related, economic, and social impacts from geothermal energy activities are underpinned by changes in institutional capacities and processes. The analysis suggests governmental actors and developers have become more effective in facilitating geothermal energy development.

Market facilitation

The CIF interventions were imperative for mobilizing capital and mitigating the financial risks and uncertainty of geothermal projects in Indonesia. These interventions were necessary given the lack of attractive geothermal PPA tariffs, which presents a barrier for developers to scale their activities as they await a more favorable regulatory environment. For example, the GCEIP project reduced upfront risks at the drilling stage, providing PGE with financial certainty that the construction of geothermal power plants would be completed. The GCEIP ultimately became profitable, with net present values of Ulubelu and Lahendong estimated respectively at $90 million and $41 million.[25] However, renegotiation of the PPA tariffs was necessary to mitigate the financial impact from drilling cost overruns.

For upstream projects, CIF loans and co-financing aim to mobilize $195 million in commercial capital by 2025 for the GEUDP, and $2 billion in commercial capital by 2029 for the GREM project.[26] This is the private capital required to complete the planned geothermal capacity additions. To this end, the financing facilities are the core focus of these upstream projects.

The interventions have also included technical assistance to solve market barriers; specifically, the GREM project has led to improved regulations regarding licensing and tariff-setting, while helping PLN to successfully implement public-private partnerships to secure private sector investments and to adopt an economic off-take pricing regime.

Policy progress and regulatory facilitation

It is difficult to establish *definitive* causal links between World Bank geothermal support and an improved enabling environment for geothermal energy development. However, the researchers find it reasonable to conclude that the continuous backing by the World Bank for more than a decade has helped propel geothermal development in Indonesia.[27] The enabling environment is now reaching a peak, with closer coordination among high-level government actors and between ministries and state-owned enterprises engaged in development. The Indonesian parties engaged in this strategic coordination are also the beneficiaries of World Bank investment and technical support, which targets both the de-risking and the demonstration of geothermal development.[28]

Recent developments suggest the MoF and the MEMR have found common ground between financing facilities, tariffs, licensing, and geothermal potential—although developers are still waiting for the new PPA regulation to catalyze these agreements. Furthermore, the MEMR and Ministry of Environment and Forestry (MoEF) have changed regulations regarding permission for geothermal project areas to be located within national parks, in effect easing the permitting process by establishing utilization zones previously designated as conservation zones.[29] The two ministries have also collaborated on screening geothermal sites in these areas through an assessment tool for screening environmental and social risks. This tool has been used for screening of geothermal sites in the GEUDP, where the World Bank is engaged in technical support while overseeing that environmental and social safeguards enable best practices and engender public acceptance of geothermal development.[30]

PGE claims to have benefitted from this evolving policy and regulatory framework, and that their good relationship with PLN, as evidenced under the GCEIP through successful renegotiation of tariffs after cost overruns, was important for the development process.[31] Furthermore, World Bank documents suggest technical assistance and capacity building under the GREM project have led MEMR to make regulatory changes to licensing and tariff-setting. PLN has successfully implemented public-private partnerships that secure private sector investments and adopted an economic off-take pricing regime. Nevertheless, the major regulatory barrier to unlock the full potential for geothermal energy is the awaited PPA regulation which can provide impetus both upstream and downstream, as developers currently have put projects on hold while waiting for an improved enabling environment. The PPA regulation is expected to support geothermal energy through mechanisms such as feed-in tariffs and by locking in a fixed price for geothermal over an extended duration.

Local institutional coordination

More effective geothermal management from government actors and their coordination with developers has proven very important for local economic development. Their common interests are exemplified by the geothermal production bonus that helps both the government and geothermal developers to maintain the continuity of geothermal production. In Lahendong, relationships and communication between local and regional government actors and developers were key success factors for project development and operations.

In terms of social facilitation, Geo Dipa Energi confirmed that the GEUDP cultivated better processes for consulting community members, civil society groups, and other stakeholders. The project included thorough disclosure of relevant information in the development process and thereby improved accountability for compliance with safeguards. Potential negative social and environmental impacts were minimized, and the community consultation process also improved targeting of positive DIs and community development plans.

Improved skills and processes

World Bank-induced capacity building has improved compliance with social and technical standards, and training programs have contributed to skills development. Capacity building under the GCEIP led to the implementation of industry best practices for technical engineering, as well as environmental and social impact assessments. PGE has transferred these industry best practices to other projects. PGE saw its staff competencies increase from assistance in preparing investment documents, advisory services, software acquisition and on-the-job training. Altogether, newly acquired technology and geological modeling skills contributed to PGE becoming a world-class developer and increasing its geothermal portfolio by identifying two new geothermal fields—in Hululais and Tompaso.

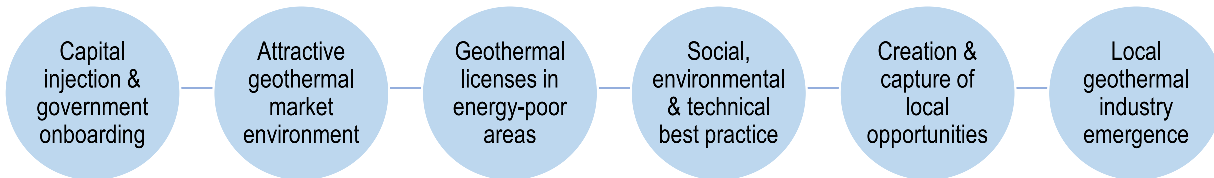
Drivers and Barriers that Affect Results

CIF investments support actual and forward-looking geothermal capacity expansion in Indonesia. In this section, we take a closer look at the underlying drivers of the DIs from these investments.

Key drivers and barriers

A chain of interlinked success factors has facilitated geothermal power development and generated DIs in Indonesia. Figure 3 illustrates drivers that provide a conducive regulatory and fiscal environment. Other key drivers include public acceptance, labor, and adequate competencies.

Figure 6. Key Success Factors



The public capital injection and onboarding of regulatory actors with different interests—notably the MEMR, MoF and MoEF—is a key starting point for exploiting the geothermal potential in Indonesia. Regulatory coordination is improving, but a major challenge that remains is to strengthen private sector confidence in geothermal energy through the PPA regulation. The GEUDP and GREM financial facility are seen as a significant step in the right direction to mitigate financial risks, but developers still find it difficult to access finance for riskier greenfield geothermal projects.[32] For these kinds of projects, the GREM facility is claimed to be inadequate in part because funds flow through several steps, which increases the interest rate on the loan.[33]

Another success factor is to prioritize geothermal baseload power generation in the electricity planning in areas with energy access gaps. It is important to issue geothermal licenses for areas that are not electrified, as increased energy access is by far the biggest contributor to socioeconomic development impacts. Fourth, development and implementation of technical, environmental, and social best practices has been shown to be an important driver; bringing the local population onboard is important for project success, as well as to capture the full extent of local economic opportunities. Lastly, findings suggest that sustained local activity in geothermal development supports and grows local supply chains. These findings reflect the fact that the emergence of the geothermal industry in Indonesia can be driven by, and largely benefit, local populations through direct and indirect employment.

The World Bank plays an important role in enhancing the fiscal and regulatory environment. The GCEIP provides evidence of successful renegotiation of PPAs. GREM assistance led MEMR to make regulatory changes to licensing and tariff-setting and helped set up PLN's public-private partnerships (PPPs) needed for adoption of an economic off-take pricing regime. Other key drivers are prominently the low interest rate loans from CIF which effectively leveraged the financial internal rate of return (IRR) in the GCEIP, as well as the financial support and creation of PPPs in the GREM, the latter of which will help to mobilize $2 billion in private capital. While the success of GREM project developments remains to be seen, it is clear that geothermal development relies on fiscal enabling and technical assistance to help developers exploit their potential. Through technical assistance, the World Bank improved financial processes and enhanced local industry standards relating to engineering quality and environmental impacts. This, together with support through training and skills development, has significantly bolstered PGE, now considered a world-class geothermal developer because of the GCEIP. Another glimpse of success, largely driven forward by the World Bank and ADB, is Geo Dipa Energi's Gender Action Plan, which integrates a gender-balanced recruitment in human resource management. Consideration for local needs and vulnerable populations is also increasingly integrated in stakeholder management plans, with public acceptance being a critical outcome.

Key remaining barriers to geothermal development relate to the fiscal and regulatory enabling environment. As indicated above, although World Bank technical assistance showcases contributions to the enabling environment, the delay of the PPA Presidential Regulations is blocking progress on the achievement of DIs. With the recent Supply Plan for 2021–2030 promoting renewable energy, the revision of regulations is expected to have a profound impact on the competitiveness of renewables versus fossil fuels, which will help to realize further DIs.[34] The World Bank can play a supporting role to mitigate regulatory and financial risks. Beyond financing, the World Bank can drive progress through technical assistance that targets the mechanisms needed to disburse the capital. Where state-owned developers may have a better risk appetite, private sector onboarding relies more heavily on risk-reducing structures, such as the economic off-take pricing regime and the PPPs that are being established under the GREM facility with the help of the World Bank. Such efforts are part of the solutions needed to de-risk development, in particular for greenfield projects where risks may be higher.

CIF and MDB Contributions to DIs

The CIF programmatic approach is targeting the vital regulatory and financial risks of geothermal development, while supporting project activities through environmental and social safeguards, and technical support to build capacity from the ground up. CIF funding plays a catalytic role by providing capital and by attracting co-financing from multilateral development banks, which, together with technical assistance, attract private capital and reduce investment risk.

Overall, CIF has steadily advanced geothermal development in Indonesia, with contributions ranging from the facilitation of dialogue between Indonesian ministries, to fiscal and regulatory technical assistance and helping developers prepare financial documents and adhere to acceptable technical standards. The presence of the CIF loan itself was, according to the PGE, instrumental to completing the brownfield development of the Lahendong and Ulubelu fields under the GCEIP and improved the project's profitability. At all levels, the CIF programmatic approach and its continuous complementary efforts have positively influenced geothermal development in a relatively difficult environment, and possibly raised the confidence in geothermal to the level needed for development to take off when remaining obstacles are overcome.[35]

It is also useful to establish the logical connection between the CIF project activities and the modeled benefits. As previously stated, CIF-backed geothermal projects in this case study amount to 2,120 MW, which is roughly half of the modeled national benefits from adding 5 percent geothermal energy in the electricity mix in 2030. The World Bank explicitly targets GEUDP and GREM forward-looking economic benefits by increasing electrification for millions of Indonesians as well as reducing GHGs and local air pollutant emissions.

In addition, social and educational benefits for vulnerable populations become evident not only from increased gender-neutral energy access, but also through demanding Gender Action Plans from developers. As exemplified from the GPGP, these can be effectively integrated into human resource management strategies, in turn resulting in large human capital benefits. By empowering Indonesian women and increasing their share in the labor force, CIF helps to mitigate a systemic issue holding back economic progress, which will have substantial impacts for the Indonesian economy.[36]

Future Opportunities: Lessons for CIF and Other Climate Funders

Development opportunities and barriers

This case study highlights numerous development opportunities. They include the mobilization of markets, GDP growth, and increased direct green employment, as well as wider indirect employment from increased energy access and reliability provided by the Indonesian geothermal industry. Many Indonesians can be lifted out of poverty if geothermal projects are targeted at vulnerable populations where energy access is low, and if women's enhanced participation objectives and socially inclusive processes are integrated. These aspects are at the core of a socially just and economically effective energy transition where geothermal plays a key role.

However, the aim of geothermal energy development to drive systemic change is somewhat hampered by an insufficient enabling environment. The case study addresses this environment while acknowledging that realizing local development benefits in the ambitious rollout of geothermal energy will rely on the emergence of local suppliers and a workforce to facilitate the transition. Both the local competitiveness of supply chains, and the onboarding of private capital markets to bring in the necessary funding, remain substantial barriers for fully unlocking DIs. In addition, the onboarding of local communities to drive public acceptance of geothermal energy is vital, since the largest opportunities for impacts lie in remote unconnected areas where social and cultural issues are deeply rooted.

Markets and institutions—enabling environment

The case study provides lessons on unlocking impacts for the geothermal enabling environment. The mitigation of resource risk—where costs accumulate with the need to drill additional wells—has improved with contingent recovery grants. These grants are being applied as an alternative to concessional finance, which was not working optimally under the GCEIP. World Bank geothermal interventions have reduced the risk of exploration drilling through a portfolio approach that more effectively targets the bottlenecks in the development pathway. With respect to technical enabling at the institutional level, World Bank assistance has proven vital to raise competencies in terms of industry best practice and familiarity with World Bank operations. These financial and technical aspects, assisted by the World Bank in different stages of development, reflect how external support for the Indonesian energy transition is most effective when part of a programmatic approach.

Maximization of economic and social impacts

Modeling results suggest economic impacts are predominantly driven by increased electrification, complemented by productivity benefits from improved education and health benefits from avoided local air pollutants. A key lesson is that geothermal development can maximize economic benefits when areas where electrification is low and/or where the electricity supply is unreliable are targeted. This also relates to strategic decision-making regarding the economic potential and characteristics of different geographies including availability of skills and labor, potential for industrial and farming activity, and locations suited for tourism. These considerations should be balanced with the needs of communities and their most vulnerable citizens to close the gap on income inequality.

Furthermore, education and gender benefits highlight how geothermal energy can derive sustained DIs while creating socioeconomic structural change. To ensure that the education rate of return from energy access reaches its full potential, complementary expenditures on the education system, such as from the geothermal production bonus, can be effective. Similarly, the rate of return for gender equality can be increased by project targets for equal access to the added geothermal energy for men and women and integrated Gender Action Plans. The latter has the possibility, through targeted recruitment, to identify and train women to take up jobs that would otherwise be unavailable to them, and thereby signal to the Indonesian society and communities the importance of creating opportunities for traditionally excluded or vulnerable citizens.

Role of CSR activities

CSR activities can play a key complementary role for the creation of sustained DIs—rather than one-off benefits—if the project developers' social investments and community development programs are closely tied to the objectives and opportunities arising from geothermal energy projects. Project developers are well placed to engage communities in targeted development activities, as they are aware local poverty and gender issues and of economic development potential. Developers should therefore be adequately incentivized to drive forward a positive developmental agenda instead of aiming for minimum compliance. The World Bank could take a more proactive role to facilitate this process—for example through an on-site task force that collaborates with the project developer.

Potential for scaling and replication

Indonesia's geothermal sector is expected to grow substantially in the coming years, enabling the findings from this study to be scaled within the sector and/or replicated to other sectors. The specificity of the geothermal resource risk should be highly relevant for the geothermal industry domestically, but also internationally for emerging and developing economies struggling with similar regulatory barriers and skills shortages. Replication of the success factors for geothermal in other sectors depends on the enabling environment (market and institutional factors) and comparable impact channels. Like geothermal energy, other renewables, including hydro and solar, should at a high level offer similar impact channels (electrification, education, health, and jobs).

Table 7 offers possible solutions to scale and replicate success factors and ideas derived from geothermal projects in this study, building on the lessons captured in the former section. These ideas can be assessed and tailored according to project characteristics to maximize the impact of climate finance.

Table 7. Potential Areas for Scaling and Replication

Impact Area	Opportunities for Scaling and Replication for Increased DIs
Markets	• World Bank loans should be at a favorable interest rate to leverage the profitability of projects • Contingent recovery grants can reduce resource risks more effectively than concessional finance • A portfolio approach[37] to geothermal exploration may be needed to reduce resource risk • Loans flowing through governmental intermediaries can raise the total interest rate • Regulatory assistance on licensing and tariff setting can mitigate PPA-related issues • PPPs and complementary mechanisms can be used to onboard private sector developers and are one of several ways to effectively disburse available financing
Institutions	• Technical assistance should aim at knowledge transfer to improve quality of developers, for example in engineering, environmental and social best practices, and financial preparations • Developers can drive socioeconomic development via integrated plans and mechanisms (e.g., Gender Action Plans, CSR plans) that proactively seek complementary community benefits. • Local governments can recycle the revenue[38] gained from geothermal electricity sales towards nearby communities (e.g., spending on education, infrastructure, vulnerable groups).
Economic and Social	• Economic impacts are maximized when capacity additions lead to increased electrification. • A socioeconomic screening of communities can help uncover its economic potential including the availability of skills and labor and economic activities that can be improved or emerge from increased access to electricity (or better reliability). • Local governments have an incentive to onboard the local community and local suppliers to foster local economic growth, and should do so in collaboration with project developers who manage the procurement processes. • Public acceptance is vital to cultivate local participation, where activities should move beyond minimum compliance to a more proactive agenda seeking positive impacts. • CSR activities can play a complementary role for sustained development impacts by supporting the community in ways which are closely tied to development objectives. • The development impact objectives should be clearly defined and structured as part of the initial project development process to capture the full potential direct and indirect benefits from projects.

Improving the programmatic approach to climate finance

At a high level, CIF's programmatic approach to climate finance is well designed and tackles in a complementary manner several key issues for geothermal energy development in Indonesia. However, to maximize DIs, geothermal projects still require maturation in the areas of private sector engagement, community onboarding, and making sure that benefits are split appropriately within the local population. These aspects can be approached more effectively by incentivizing project developers and local governments to address them within integrated plans and mechanisms embedded in project activities. There are signs of this already happening.

Some of the best practices found from this case study include the technical assistance that helped PGE become a world-class project developer; the geothermal production bonus that recycles tax revenue to the local communities; and Geo Dipa Energi's creation of Gender Action Plans. While we find CSR activities to largely reflect the types of DIs that emerge from geothermal energy development, these should be more closely interlinked to make sure that all efforts create impacts on a sustained long-term basis and for the benefit of the whole community. This linkage can be informed by conducting a socioeconomic screening of the community in question, to identify local attributes and needs to address during project development.

Sub-Appendix 6A. Data Sources

Data for this case study were collected primarily from document review, interviews, and site visits. These data sources provided input that IEc used to conduct economy-wide modeling.

Document review

World Bank and ADB documents explain the nature and objectives of the geothermal projects. For the downstream GCEIP completed in 2018, the World Bank database enabled the extraction of actual results and provided helpful direction through a draft theory of change. For the GPGP and the upstream GEUDP and GREM projects—all ongoing—World Bank and ADB documents indicated the activities performed in the interventions, while signaling that the intended impacts are forward looking. The developer under the GEUDP and GPGP—Geo Dipa Energi—shared a few documents on the impact of CIF funds for the project, which helped us to map and quantify several impact indicators. For the GREM project we relied largely on World Bank implementation status reports. Other data sources include contextual documents, journal articles, reports, and news articles.

Since upstream projects have not been completed, and because their aim is to de-risk geothermal development, the data available are of a different character than the information from the completed and ongoing downstream projects. Unpacking the actual tangible impacts upstream is more difficult because project activities are relatively more focused on the mechanisms and issues related to the enabling environment. Still, secondary data collected from the GEUDP provided insights into the community sentiment of geothermal development in real-time, in addition to the fiscal and regulatory de-risking aspects that lie at the core of the project. Given the forward-looking nature of upstream projects, and their key objective to enhance energy access in the long term, we analyze the impacts of these projects more closely with CGE modeling.

Interviews and site visits

The document review became a springboard for iterative primary data collection. A total of 21 interviews were conducted with key stakeholders, guided by the World Bank's advice and introductory calls with the relevant Indonesian ministries. An extensive site visit was made to North Sulawesi in the Lahendong area to capture insights from a variety of local stakeholders. On-site interviews were held with the key developer, the main local governmental agencies, as well as other community beneficiaries and local businesses.

Modeling approach

In addition to qualitative data collection and analysis, the case study includes economic modeling to quantify the economic benefits, emission reductions, and job creation from geothermal expansion in Indonesia. The modeled economic benefits arise from increased electrification, increased access to education and the resulting increase in productivity, and health impacts from reduced air pollution. The modeling examines impacts in 2030 and 2045 based on the share of new geothermal power in the electricity mix in 2030 and 2045, ranging from 1 to 15 percent, and different geothermal levelized cost settings ranging from $25/MWh to $100/MWh. Further details are provided in Sub-Appendix 6B.

List of Interviewees

** In the few cases where the interviewee preferred to be anonymous a general title is provided.*

*** On-site interviews were made in Lahendong, North Sulawesi for the GCEIP. Where location is not applicable (n/a), interviewees provide insights for the case study as a whole.*

Organization	Name and Job Title*	Project, location**
Ministry of Energy and Mineral Resources, Directorate General of New, Renewable Energy and Energy Conservation, Directorate of Geothermal	Harris (Mr) – Director of Geothermal Sahat Simangunsong (Mr) -Head of Sub-directorate of Geothermal Investment and Cooperation	n/a
Ministry of Finance, Directorate General of Budget Financing and Risk Management	Heri Setiawan (Mr) – Director, State Financial Risk Management	n/a
Fiscal Policy Agency (BKF)	Dian Lestari (Ms) – Director of Center for Climate Finance and Multilateral Policy Dalyono (Mr) Section Head – Climate and Multilateral Policy Analysis)	n/a
Pertamina Geothermal Energy – Lahendong Area	Jati Permana (Mr) – Planning Manager Manda Wijaya (Mr) – Operational Manager Dimas Wibisono (Mr) – Government Relation	GCEIP, Lahendong
PT Sarana Multi Infrastruktur	Adyaksa Paripurna (Mr) – Sustainable Financing Division	GEUDP, Waesano & Jailolo
Municipal Secretary of Minahasa Regency	Wenny Talumena (Mr) – Assistant in Economic and Development	GCEIP, Lahendong
Department of Environment at Minahasa Regency	Feby (Ms) – Section Head, Environmental Pollution Control	GCEIP, Lahendong
South Tomohon sub-regency/district office	Selfie F. Datu (Ms) – Head of South Tomohon Sub-regency/district Office	GCEIP, Lahendong
Tompaso sub-regency/district office	Meryl Bewekat (Mr) – Head of Planning	GCEIP, Lahendong
Masarang Foundation	Willie Smith (Mr) – Head of foundation Harry Kaunang (Mr) – Head of Masarang Sugar Factory Dita Mantiri – Masarang Sugar Factory Operational	GCEIP, Lahendong
Head of Lahendong Village	Felix (Mr) – Head of village	GCEIP, Lahendong
Head of Toure Village	Alvian (Mr) – Head of village	GCEIP, Lahendong
Head of Sendangan Village	Deske (Mr) – Head of village	GCEIP, Lahendong
Head of Talikuran Village	Paulus Tuju (Mr) – Head of village	GCEIP, Lahendong
Local business: Sendagan Village-owned Enterprise	Ayen (Mr) – Head of Village-owned Enterprise	GCEIP, Lahendong
Local business: Women's Sewing Group Maria	Linda Wowor (Ms) – Leader of Women's Sewing Group Toure Village	GCEIP, Lahendong

Organization	Name and Job Title*	Project, location**
A global international Independent Power Producer	Geothermal project developer	n/a
A geothermal regulatory expert from the key ministries during the development of GEUDP and GREM program	Geothermal expert	n/a
A geothermal expert who was involved in Geodipa's Dieng Geothermal Power Plant projects	Geothermal practitioner	n/a
World Bank	Peter Johansen (Mr) – Senior Energy Specialist and Task Team Leader, Muchsin Qadir (Mr) – Energy Specialist	n/a
International Energy Agency	Randi Kristiansen (Ms) – Economics and Financial Analyst Kieran Clarke (Mr) – South East Asia Programme Manager Nathaniel Lewis (Mr) – South East Asia Programme Officer	n/a

Sub-Appendix 6B. Economy-Wide Modeling of Expanding Geothermal Power Generation in Indonesia[39]

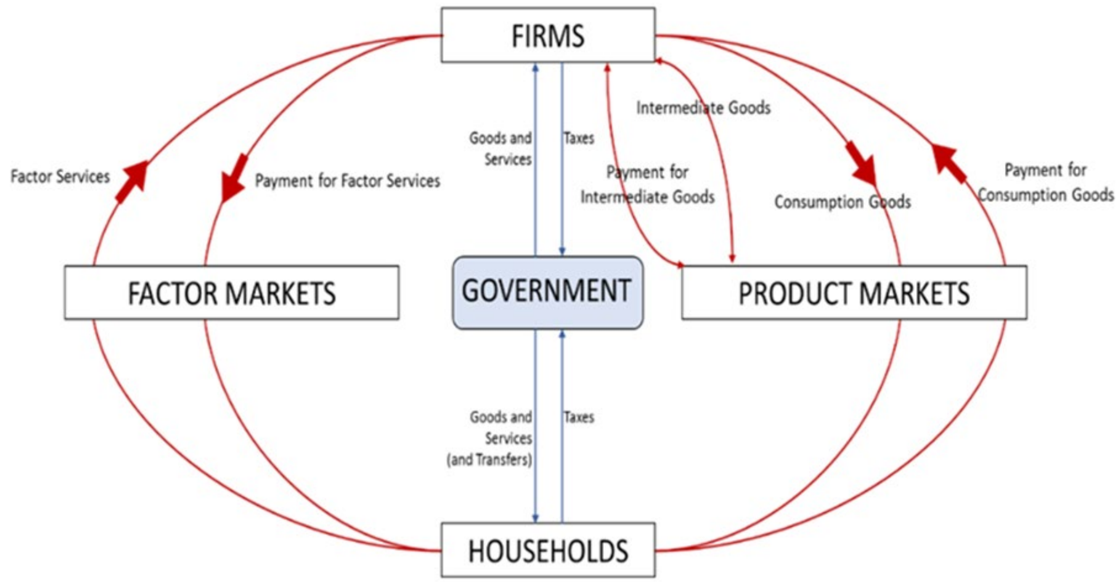
Evaluating the impacts of expanding low-carbon options is crucial for an efficient deployment of public and private funding for energy transitions and sustainable development. In this paper, we describe how an economy-wide model can be applied for such tasks. We use an example of expanding geothermal power generation in Indonesia to illustrate the approach for quantifying the economy-wide benefits and costs of technology expansion at a macroeconomic level. We test different shares of geothermal power (1, 5, 10, and 15 percent of total electricity generation) that would be forced by a government policy and evaluate economy-wide implications under different assumptions of the levelized cost of geothermal energy. Low-cost scenarios can be used as an illustration of financial support to geothermal projects from governments or international financial organizations.

While we base our evaluations on a scenario for Indonesia's energy sector development, our goal is not to assess Indonesia's policy proposals and their likely effectiveness, or project the most likely future energy mix. We do not impose any carbon pricing or overall renewable energy targets. Rather, here we show how this type of modeling can be used to evaluate the benefits of geothermal energy expansion. The insights gained from that evaluation can then be qualitatively connected to government policies, but a modeling analysis of Indonesia's climate and energy policies is outside the scope of this paper.

Model description

Economy-wide modeling is an important tool to quantify trade-offs of different policy and business decisions. We develop an economy-wide computable general equilibrium (CGE) tool to numerically estimate the impact of expanded geothermal power on Indonesia's economy. Our model represents interactions among three types of agents: households, firms, and the government, as illustrated in Figure A2-1. Households/government own the primary factors of production (labor, capital, land, and natural resources) which they rent to firms and use this income to purchase goods and services. In each sector, firms produce commodities by combining factors of production and intermediate inputs (i.e., goods produced by other sectors). The government sets policies and collects tax revenue, which it spends on providing goods and services for households and on transfer payments to households. Equilibrium is obtained through a series of markets (for both factors of production and goods and services) that determine prices so that supply equals demand.

Figure A2-1. Structure of Indonesia Economy-Wide Model



An important characteristic of CGE models is the representation of inter-sectoral linkages through each firm's use of intermediate inputs. Purchases of intermediate inputs are captured in input-output tables used to calibrate CGE models. For each sector, these tables list the value of output produced and the value of each input used, which can be linked to physical quantities (e.g., tons of coal or liters of water). For example, the manufacturing sector will use inputs of capital and labor, and outputs from the other economic sectors that are used as intermediate inputs to produce manufacturing output. These inter-sectoral linkages allow CGE models to evaluate how policy changes will propagate throughout an economy.

Other key features of CGE models include the representation of competition from competing technologies/sectors and substitution possibilities among inputs. For instance, an increase in the price of coal-based electricity will provide scope for the expansion of electricity generation from other sources, such as renewable electricity. At the same time, an increase in electricity prices will incentivize firms to use electricity more efficiently by investing in more efficient plants, at an additional cost, than they would have in the absence of the price increase. CGE models combine general equilibrium theory with realistic economic data to solve numerically for the levels of supply, demand and prices that support equilibrium across all markets.

Our CGE model of Indonesia includes a forward calibration to 2030 and 2045. It produces estimates for Indonesia's economy under alternative technology, policy and geothermal scenarios in 2030 and 2045, but it does not focus on the transition path between now, 2030 and 2045. We calibrate the model using the Global Trade Analysis Project (GTAP) database (https://www.gtap.agecon.purdue.edu/). We extract data for Indonesia and aggregate it into sectors. We also include the data on non-CO_2 emissions and estimates of non-combustion CO_2 emissions from country reports to the UN Framework Convention on

Climate Change (UNFCCC) as documented in Paltsev et al. (2018).[40] The base data provides a snapshot of economic transactions in 2014 (the latest available data in the GTAP dataset). We use the model to evaluate outcomes in 2030 and 2045 using a forward calibration procedure outlined by Winchester and Reilly (2019).

The calibration procedure creates projections for economic, energy, and GHG emission outcomes in Indonesia based on improvements in total factor productivity to target GDP estimates from the World Bank (2021)[41] and technology specific factors for electricity generation to target non-geothermal electricity outputs calibrated to Paltsev et al. (2018). Based on Chen et al. (2016),[42] we impose autonomous energy efficiency improvements of 1.5 percent per year in fossil fuel use, and a 0.3 percent annual efficiency improvement in electricity use. In the policy scenarios, total factor productivity is exogenous (and equal to values derived in the calibration procedure) and GDP is endogenous.

The sectoral aggregation of the model for Indonesia is outlined in Table A2-1. The model has 25 sectors and four factors (capital, labor, land, and natural resources). It represents 10 sectors related to energy extraction, production and distribution, including five electricity generation technologies (coal, gas, oil, renewables [hydro, wind, and solar], and geothermal). The model also represents five energy-intensive manufacturing sectors (chemical, rubber, and plastic products; non-metallic minerals; iron and steel; non-ferrous metals; and fabricated metal products) and three other manufacturing sectors (food manufacturing; motor vehicles and parts; and other manufacturing). Due to its significance, paddy rice is separated from other agriculture. Other sectors represented in the model include other mining, transportation, services, human health, and water supply and sewerage.

Table A2-1. Sectoral Aggregation

Sectors			
cru	Crude oil extraction	Pdr	Paddy rice
oil	Refined oil products	Agr	Other agriculture
col	Coal extraction	Omn	Other mining
gas	Natural gas extraction and distribution	Crp	Chemical, rubber, plastic products
ecoa	Coal electricity	Nmm	Non-Metallic Minerals (e.g., cement)
egas	Gas electricity	i_s	Iron and steel
eoil	Oil electricity	Nfm	Non-ferrous metals
eren	Renewable electricity (hydro, wind & solar)	Fmp	Fabricated metal products
egeo	Geothermal electricity	Fod	Food processing
tnd	Electricity transmission and distribution	Mvh	Motor vehicles and parts
hht	Human health and social work	Omf	Other manufacturing
wtr	Water supply and sewerage	Trn	Transportation
ser	Services		

Scenarios

In 2020, about 82 percent of Indonesia’s power generation came from fossil fuel sources (62 percent coal, 18 percent natural gas, and 2 percent oil), 6 percent came from hydropower, 8 percent came from non-hydro renewable energy, and 4 percent came from other sources, such as biomass. Geothermal accounts for the majority (96 percent) of non-hydro renewable energy. Most of Indonesia's electricity is used by residential customers (46 percent), followed by industrial (30 percent) and commercial (18 percent) users. Other uses of electricity account for 6 percent.

To estimate the impacts of expanded geothermal power on Indonesia's economy, we explore a number of scenarios, summarized in Table A2-2. For each scenario setting, we consider three different cost assumptions for geothermal power generation. Based on IEA (2020) data that provides a consistent comparison of power generation costs in different countries, we use two settings (*highcostgeo* and *basecostgeo*) when geothermal costs are higher than coal-based generation costs in Indonesia.[43] These settings correspond to levelized costs of geothermal electricity of $100/MWh and $50/MWh, respectively. For these two settings, we test different shares of geothermal power (1, 5, 10, and 15 percent of total electricity generation) that would be forced by a government policy.

We also consider a scenario when the geothermal cost ($25/MWh) is lower than coal-based generation cost. We calibrate this case on the IEA's 2017 Southeast Asia Energy Outlook,[44] which reports for Indonesia these extremely low geothermal costs. We call this setting *lowcostgeo*. This setting can be used to evaluate the impacts of financial support that would lower the levelized cost of geothermal electricity (by subsidizing capital expenditures or other channels). In this setting, rather than forcing different shares of geothermal, we constrain geothermal power generation to its maximum potential. According to ADB (2018),[45] geothermal potential capacity in Indonesia is 29 GW, which under normal conditions translates to about 200 TWh of electricity production.

The shares of geothermal power in our scenarios are chosen from an estimate of geothermal potential in Indonesia and projected electricity demand. According to IEA (2021), the power generation system in Indonesia had 63 GW of installed generation capacity and generated 275 TWh of electricity in 2020. Based on expected population and GDP growth, we project a substantial increase in electricity use in Indonesia, reaching about 700 TWh in 2030 and about 1100 TWh in 2045. If all geothermal potential were to be developed, it would account for about 30 percent of the expected electricity consumption in Indonesia in 2030 and about 15 percent of expected electricity consumption in 2045. With the current installed geothermal capacity of less than 2 GW, it is unlikely that by 2030 the full geothermal capacity will be developed. Hence, we bound most of our scenarios at a 15 percent share of geothermal power in total electricity generation in 2030 and 2045.

Table A2-2. Scenarios

Scenario Setting	Scenario Name	Geothermal Shares Explored 1%	5%	10%	15%
(1) Base Setting (no impact channels)	Base-highcostgeo	✓	✓	✓	✓
	Base-basecostgeo	✓	✓	✓	✓
	Base-lowcostgeo				
(2) Increased Electrification	Elec-highcostgeo	✓	✓	✓	✓
	Elec-basecostgeo	✓	✓	✓	✓
	Elec-lowcostgeo				
(3) Increased Electrification + Education Benefits	ElecEd-highcostgeo	✓	✓	✓	✓
	ElecEd-basecostgeo	✓	✓	✓	✓
	ElecEd-lowcostgeo				
(4) Health Impacts of Geothermal	Health-highcostgeo	✓	✓	✓	✓
	Health-basecostgeo	✓	✓	✓	✓
	Health-lowcostgeo				
(5) All Impact Channels Together	All-highcostgeo	✓	✓	✓	✓
	All-basecostgeo	✓	✓	✓	✓
	All-lowcostgeo				

To assess the economy-wide impacts of developing geothermal power, we consider the following impact channels:

(A) **Increased electrification:** We assume new geothermal projects provide access to electricity to areas with no previous access in proportion to the share of geothermal (e.g., a 10 percent share of new geothermal increases electrification by 10 percent). That increase in electrification has direct economic benefits through increased productivity growth, higher income and higher consumption. This scenario can be considered as an “upper bound” for potential electrification benefits because we assume that all new geothermal contributes to increased electrification. In reality, the electrification benefits of geothermal are likely to be concentrated in remote areas and remote islands; geothermal might not provide much electrification benefit in the more developed mainland which already has reliable electricity.

(B) **Education benefits of increased electrification:** Increased electrification also has indirect benefits through increased education and, in turn, increased labor productivity. As electrification increases with increased geothermal, we assume a proportional increase in the number of people with access to an incremental additional amount of education and therefore higher labor productivity (e.g., a 10 percent share of new geothermal increases electrification by 10 percent, which increases the number of people with access to further education by 10 percent). Then, based on Makarov et al. (2020),[46] we assume an education rate of return on labor productivity of 12 percent. The education rate of return shows an increase in labor productivity of educated workers in comparison to their productivity without additional education. For example, a 10 percent increase in geothermal leads to an incremental additional amount of education for 10 percent of the population, who would become 12 percent more productive than they are in the reference case.

(C) **Air pollution health impacts:** Because geothermal power does not generate harmful air pollutants, and it reduces the use of fossil-based technologies which do, expanded geothermal has health benefits. Based on Dimanchev et al. (2019),[47] we assume health benefits of \$0.08/kWh of geothermal. This number represents an aggregate value of health benefits of reducing $PM_{2.5}$ (formed by SO_2, NO_X, NH_3, and VOC) in a coal-dominated electricity system, when a larger share of renewables is forced into the generation mix.

Since one cannot have the education benefits of electrification without the increased electrification, we have developed the following five cases, which are each explored for the three geothermal cost assumptions and the four different shares of geothermal requirements for the higher cost settings:

(1) Base Setting (no impact channels)

(2) Increased Electrification

(3) Increased Electrification + Education Benefits

(4) Health Impacts of Geothermal

(5) All Impact Channels Together (increased electrification, education benefits and health impacts).

It should be noted that we consider illustrative scenarios here. A number of caveats need to be addressed in further work. First, additional analysis is required to quantify the shares of electrification benefits (rather than the upper limits as we consider here). This would entail a detailed geographic assessment of the current electrification/reliability rates and locations of geothermal projects. Also, it is expected that over time electrification benefits would decrease because more and more areas would be already reliably electrified.

Second, for education benefits we have used an education rate of return of 12 percent, which is based on instrumental variable studies for Australia (Leigh and Ryan 2008)[48] and Russia (Makarov et al. 2020).[49] Similar rates of about 10 percent have been estimated for the U.S., Canada, Norway, Russia and other countries, but a targeted study for Indonesia would help to confirm the applicability of this rate to the Indonesian context.

For air pollution benefits we used a simplified approach by applying a U.S.-based study of air pollution-related health effects, where coal-based generation is replaced by renewables (wind and solar). The actual benefits would depend on local conditions, including climatic conditions, what fuel source was displaced, etc. A specific air pollution study for Indonesia needs to be conducted for finer resolved health impacts of air pollution. For example, one approach would be to use marginal atmospheric sensitivities to emissions from the adjoint of the global chemistry-transport model in combination with concentration response functions and the value of statistical life (Grobler et al. 2019).[50] Another approach is to use the results of an economy-wide model like we deploy in this report and connect the results with a reduced-form air pollution model like in Dimanchev et al. (2019), but rather than assuming aggregate health benefits of \$0.08/kWh when renewable energy replaces coal, to calculate the impacts from reducing a particular pollutant like $PM_{2.5}$, NO_x, or SO_2. These approaches would require a special Indonesia-based air pollution study using a simplified or full-scale air pollution model.

Another possible extension of the approach used in this study is adding distributional details (i.e., different income groups, urban/rural population, etc.) to the economy-wide modeling. In the current setting, the model has a representative agent that aggregates consumption behavior for a whole country. Merging the input-output structure of an economy-wide CGE model with detailed expenditures surveys for Indonesia would allow for the consideration of distributional impacts of different policies (see, for example, Garcia-Muros et al. 2022).[51]

Finally, there are numerous policy proposals related to low-carbon electricity deployment and economy-wide emission reductions, including a net-zero target for Indonesia by 2060 communicated by the Government of Indonesia to the UNFCCC. In this report we focus on the pathways for evaluating the benefits of geothermal power rather than on an assessment of government goals and announcements. For an assessment of the gap between the stated goals for the Paris Agreement process and actual development, see Paltsev et al. (2018) and Climate Action Tracker.[52]

Results

We explore the impacts of expanded geothermal on GDP, emissions, labor in the electricity sector, and the electricity mix. We also scale our results to provide the estimates of impacts for two geothermal projects: Ulubelu and Lahendong.

Base-setting results

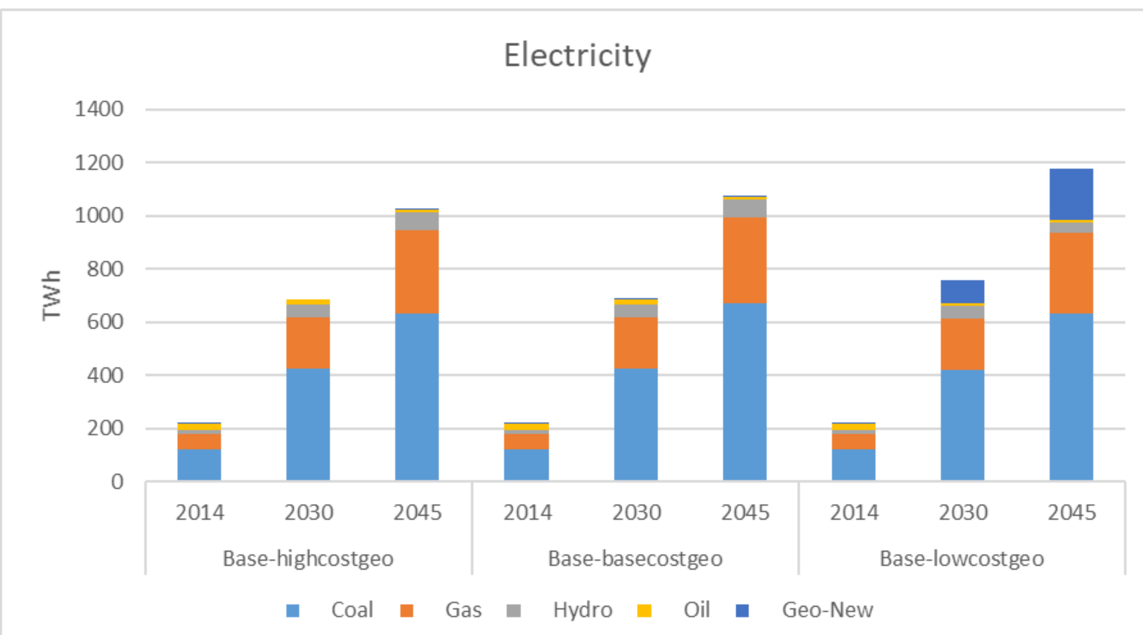
First, we look at results under the Base Setting with the different geothermal cost assumptions (*highcostgeo*, *basecostgeo*, and *lowcostgeo*). The results are provided in Table A2-3. Because we are interested in the impacts of newly installed geothermal capacity, we report the results for geothermal by separating newly built geothermal (Geo-New) and total geothermal (Total Geo). Under the Base Setting, there is very little new geothermal developed under both *highcostgeo* and *basecostgeo* scenarios. Other electricity technologies prove more economical when not accounting for the benefits of geothermal. In contrast, in the *lowcostgeo* scenario, geothermal generation reaches its full capacity by 2045.

Table A2-3. Base Setting Results

	Benchmark	Base-highcostgeo		Base-basecostgeo		Base-lowcostgeo	
	2014	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**
GDP (billion 2014$)	843.2	1985.8	3571.9	1985.8	3576.5	1985.8	3578.0
Emissions (mmtCO2e)	733.9	1483.6	2365.1	1483.4	2419.6	1478.3	2387.1
Labor in Elec Sector ($)	0.1	0.3	0.9	0.3	0.8	0.5	1.3
Labor in Coal Elec ($)	0.0	0.2	0.6	0.2	0.6	0.2	0.5
Labor in Geo Elec ($)	0.0	0.0	0.0	0.0	0.0	0.2	0.6
Electricity (TWh)	222.3	684.1	1022.4	684.3	1071.7	756.2	1175.5
Coal	120.6	423.4	631.9	423.2	668.1	420.6	629.6
Gas	57.9	194.2	314.9	194.1	327.3	192.8	306.1
Hydro	15.2	48.5	65.2	48.5	65.2	48.5	39.4
Oil	22.7	18.1	10.3	18.1	10.3	6.4	6.2
Geo-New	5.9	0.0	0.0	0.4	0.8	87.8	194.1
% Geo-New	**3%**	**0%**	**0%**	**0%**	**0%**	**12%**	**17%**
Total Geo (TWh)	**5.9**	**5.9**	**5.9**	**6.3**	**6.7**	**93.7**	**200.0**

Figure A2-2 illustrates the generation mix in Indonesia in 2030 and 2045 under the Base Setting, where coal keeps a substantial share. As there is little difference in the electricity mix between the *basecostgeo* and *highcostgeo*, there are also only small differences in the other outcomes for these settings reported in Table A2-3. However, the *lowcostgeo* scenario results in geothermal affecting other generation technologies.

Figure A2-2. Base Setting Results for Electricity Production in Indonesia



Next, we look at the results in the Base Setting with expanded geothermal under the *basecostgeo* and *highcostgeo* scenarios (Tables A2-4 and A2-5). In this setting, we have imposed a requirement that a certain share of power generation should come from geothermal power (1, 5, 10, and 15 percent) under two different cost assumptions for geothermal (levelized cost of $100/MWh and $50/MWh).[53] Note that the levelized cost of coal-based generation is about $40/MWh and natural gas-based generation is about $60/MWh (capital costs of coal and gas power plants are similar to plants in China and India and about half of the costs in Europe, the U.S., and Japan due to different environmental and other characteristics.[54] With increasing shares of geothermal, economy-wide GHG emissions are reduced. However, without accounting for positive externalities of geothermal power (i.e., the impact channels discussed above), such an expansion has an overall negative impact on GDP because geothermal is more expensive than other sources of power.

Table A2-4. Impacts of expanding geothermal in the Base Setting with the high cost of geothermal

	Benchmark	Reference		1% Geothermal		5% Geothermal		10% Geothermal		15% Geothermal	
	2014	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**
GDP (billion 2014$)	843.2	1985.8	3571.9	1985.3	3571.6	1983.3	3570.3	1980.5	3568.5	1977.6	3566.6
Emissions (mmtCO2e)	733.9	1483.6	2365.1	1482.9	2363.0	1483.9	2354.3	1478.3	2342.7	1460.7	2329.9
Labor in Elec Sector ($)	0.1	0.3	0.9	0.4	1.0	0.6	1.4	0.9	2.0	1.3	2.6
Labor in Coal Elec ($)	0.05	0.22	0.62	0.22	0.61	0.22	0.59	0.21	0.57	0.20	0.54
Labor in Geo Elec ($)	0.01	0.00	0.00	0.06	0.11	0.31	0.58	0.64	1.19	0.99	1.84
Electricity (TWh)	222.3	684.1	1022.4	688.3	1027.4	710.5	1048.1	730.5	1074.5	732.4	1101.2
Coal	120.6	423.4	631.9	422.7	628.6	424.8	615.0	418.3	596.9	396.3	577.4
Gas	57.9	194.2	314.9	193.7	313.0	194.5	305.1	190.4	294.6	177.9	283.0
Hydro	15.2	48.5	65.2	48.5	65.2	48.5	65.2	48.5	65.2	48.4	65.2
Oil	22.7	18.1	10.3	16.6	10.3	7.3	10.3	0.3	10.3		10.3
Geo-New	5.9	0.00	0.01	6.9	10.2	35.5	52.4	73.0	107.5	109.9	165.2
% Geo-New	**3%**	**0%**	**0%**	**1%**	**1%**	**5%**	**5%**	**10%**	**10%**	**15%**	**15%**
Total Geo	**5.9**	**5.9**	**5.9**	**12.8**	**16.1**	**41.4**	**58.3**	**78.9**	**113.4**	**115.8**	**171.1**

Table A2-5. Impacts of expanding geothermal in the Base Setting with the base cost of geothermal

	Benchmark	Reference		1% Geothermal		5% Geothermal		10% Geothermal		15% Geothermal	
	2014	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**
GDP (billion 2014$)	843.2	1985.8	3576.5	1985.7	3576.5	1985.0	3576.3	1984.1	3576.0	1982.9	3575.7
Emissions (mmtCO2e)	733.9	1483.4	2419.6	1482.4	2417.7	1482.1	2409.4	1480.1	2398.3	1469.8	2386.1
Labor in Elec Sector ($)	0.1	0.3	0.8	0.4	0.9	0.5	1.1	0.6	1.4	0.8	1.7
Labor in Coal Elec ($)	0.05	0.22	0.60	0.22	0.60	0.22	0.58	0.22	0.56	0.21	0.54
Labor in Geo Elec ($)	0.01	0.00	0.00	0.03	0.06	0.15	0.30	0.32	0.63	0.52	0.97
Electricity (TWh)	222.3	684.3	1071.7	688.5	1077.8	712.3	1104.8	742.2	1140.3	761.3	1175.5
Coal	120.6	423.2	668.1	422.1	665.6	422.8	654.4	421.7	639.4	411.5	622.1
Gas	57.9	194.1	327.3	193.5	325.9	193.8	319.7	193.1	311.3	187.1	301.7
Hydro	15.2	48.5	65.2	48.5	65.2	48.5	65.2	48.5	65.2	48.5	65.1
Oil	22.7	18.1	10.3	17.5	10.3	11.7	10.3	4.8	10.3	0.0	10.3
Geo-New	5.9	0.4	0.8	6.9	10.8	35.6	55.2	74.2	114.0	114.2	176.3
% Geo-New	**3%**	**0%**	**0%**	**1%**	**1%**	**5%**	**5%**	**10%**	**10%**	**15%**	**15%**
Total Geo	**5.9**	**6.3**	**6.7**	**12.8**	**16.7**	**41.5**	**61.1**	**80.1**	**119.9**	**120.1**	**182.2**

As shown in Tables A2-4 and A2-5, even in the high and base cost scenarios, there are positive impacts of expanded geothermal generation on economy-wide CO_2 emissions in Indonesia. Achieving a 15 percent share of geothermal leads to a reduction of about 20 Mt CO_2 in 2030 and about 35 Mt CO_2 in 2045. CO_2 emission reduction benefits in the *lowcostgeo* scenario (Table A2-6) are comparable to the 15 percent share cases of the *highcostgeo* and *basecostgeo* scenarios, because under the low cost a similar level of geothermal generation is achieved without any imposed requirements.

Table A2-6. Impacts of expanding geothermal in the Base Setting with the low cost of geothermal

	Benchmark	Reference	
	2014	**2030**	**2045**
GDP (billion 2014$)	843.2	1985.8	3578.0
Emissions (mmtCO2e)	733.9	1478.3	2387.1
Labor in Elec Sector ($)	0.1	0.5	1.3
Labor in Coal Elec ($)	0.05	0.22	0.55
Labor in Geo Elec ($)	0.01	0.20	0.60
Electricity (TWh)	222.3	756.2	1175.5
Coal	120.6	420.6	629.6
Gas	57.9	192.8	306.1
Hydro	15.2	48.5	39.4
Oil	22.7	6.4	6.2
Geo-New	5.9	87.8	194.1
% Geo-New	**3%**	**12%**	**17%**
Total Geo	**5.9**	**93.7**	**200.0**

Increased Electrification results

In the Increased Electrification setting with expanded geothermal, we explore the potential for benefits of geothermal power when it is deployed in locations that currently do not have access to electricity. Electrification and transition to modern energy services lead to poverty reduction and development. There are different channels for productivity and economic growth increases due to electrification. For example, Aragaw (2012)[55] investigated benefits of electrification for the case of Ethiopia and provided an assessment of numerous impacts, including: improved access to information and communication; business creation, employment generation, and increasing household income; and improved social services, such as health services, water supply and sanitation, street lighting that improved security and resulted in improved quality of life, better access to vaccination due to availability of refrigeration, and improved use of medical and other equipment.

In our modeling, we have applied an aggregate approach and rather than quantifying individual impacts as in Aragaw (2012), we have estimated an increase in aggregated private consumption in Indonesia due to increased electrification that geothermal can provide (see above for a description of our approach). As mentioned before, the results can be considered as an upper bound of benefits because in reality the full amount of new geothermal might not be dedicated to increased electrification.

Developing geothermal in the areas without access to electricity leads to substantial positive economic benefits (Tables A2-7 and A2-8). In the case when 15 percent of power generation is supplied by geothermal and leads to a 15 percent increase in electrification, Indonesia's GDP grows by 10–12 percent in 2030–2045 relative to the case of no improvement in electrification.

Table A2-7. Impacts of expanding geothermal in the Increased Electrification setting with the high cost of geothermal

	Benchmark	Reference		1% Geothermal		5% Geothermal		10% Geothermal		15% Geothermal	
	2014	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**
GDP (billion 2014$)	843.2	1985.8	3571.9	1998.1	3601.9	2048.6	3707.2	2115.0	3847.5	2185.4	3998.7
Emissions (mmtCO2e)	733.9	1483.6	2365.1	1482.9	2418.5	1484.4	2413.2	1483.5	2406.0	1472.6	2398.2
Labor in Elec Sector ($)	0.1	0.3	0.9	0.4	1.0	0.6	1.4	1.0	2.0	1.3	2.7
Labor in Coal Elec ($)	0.05	0.22	0.62	0.22	0.60	0.22	0.58	0.21	0.56	0.20	0.54
Labor in Geo Elec ($)	0.01	0.00	0.00	0.06	0.12	0.31	0.61	0.65	1.26	1.01	1.95
Electricity (TWh)	222.3	684.1	1022.4	688.8	1078.4	714.0	1108.0	743.7	1147.3	759.7	1188.8
Coal	120.6	423.4	631.9	422.5	666.1	424.7	656.9	423.7	644.6	410.6	631.1
Gas	57.9	194.2	314.9	193.7	326.0	194.7	320.3	193.9	312.6	186.2	304.1
Hydro	15.2	48.5	65.2	48.5	65.2	48.5	65.2	48.5	65.2	48.5	65.2
Oil	22.7	18.1	10.3	17.2	10.3	10.1	10.3	2.6	10.3		10.3
Geo-New	5.9		0.0	6.9	10.7	36.1	55.3	75.1	114.5	114.4	178.0
% Geo-New	**3%**	**0%**	**0%**	**1%**	**1%**	**5%**	**5%**	**10%**	**10%**	**15%**	**15%**
Total Geo	**5.9**	**5.9**	**5.9**	**12.8**	**16.6**	**42.0**	**61.2**	**81.0**	**120.4**	**120.3**	**183.9**

Table A2-8. Impacts of expanding geothermal in the Increased Electrification Setting with the base cost of geothermal

	Benchmark	Reference		1% Geothermal		5% Geothermal		10% Geothermal		15% Geothermal	
	2014	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**
GDP (billion 2014$)	843.2	1985.8	3576.5	1998.4	3602.3	2050.4	3708.9	2119.0	3851.4	2191.6	4005.0
Emissions (mmtCO2e)	733.9	1483.4	2419.6	1482.5	2419.0	1482.4	2416.0	1482.3	2411.8	1478.3	2406.8
Labor in Elec Sector ($)	0.1	0.3	0.8	0.4	0.9	0.5	1.1	0.7	1.5	0.8	1.8
Labor in Coal Elec ($)	0.05	0.22	0.60	0.22	0.60	0.22	0.59	0.21	0.58	0.21	0.56
Labor in Geo Elec ($)	0.01	0.00	0.00	0.03	0.06	0.16	0.31	0.33	0.64	0.54	1.00
Electricity (TWh)	222.3	684.3	1071.7	689.1	1080.2	715.6	1117.6	751.8	1168.1	783.1	1222.8
Coal	120.6	423.2	668.1	422.1	667.2	422.4	662.3	423.1	655.4	421.0	647.5
Gas	57.9	194.1	327.3	193.5	326.7	193.8	323.8	194.3	319.9	192.9	315.2
Hydro	15.2	48.5	65.2	48.5	65.2	48.5	65.2	48.5	65.2	48.5	65.2
Oil	22.7	18.1	10.3	18.1	10.3	14.8	10.3	9.5	10.3	2.2	10.3
Geo-New	5.9	0.4	0.8	6.9	10.8	36.2	55.9	76.4	117.2	118.6	184.5
% Geo-New	**3%**	**0%**	**0%**	**1%**	**1%**	**5%**	**5%**	**10%**	**10%**	**15%**	**15%**
Total Geo	**5.9**	**6.3**	**6.7**	**12.8**	**16.7**	**42.1**	**61.8**	**82.3**	**123.1**	**124.5**	**190.4**

Focusing on the results when the share of geothermal is pushed to 15 percent, electrification benefits amount to about $200 billion in 2030 and about $430 billion in 2045 in comparison to the reference scenario. In the *lowcostgeo* scenario, the share of geothermal in total power generation reaches 16 percent in 2045 (Table A2-9). The electrification benefits are even higher in this case and they amount to about $495 billion in 2045.

Table A2-9. Impacts of expanding geothermal in the Increased Electrification Setting with the low cost of geothermal

	Benchmark	**Reference**	
	2014	**2030**	**2045**
GDP (billion 2014$)	843.2	2150.0	4072.6
Emissions (mmtCO2e)	733.9	1479.7	2412.1
Labor in Elec Sector ($)	0.1	0.5	1.4
Labor in Coal Elec ($)	0.05	0.21	0.58
Labor in Geo Elec ($)	0.01	0.20	0.59
Electricity (TWh)	222.3	767.9	1220.9
Coal	120.6	420.6	659.6
Gas	57.9	193.4	322.0
Hydro	15.2	50.1	39.0
Oil	22.7	13.3	6.2
Geo-New	5.9	90.5	194.1
% Geo-New	**3%**	**12%**	**16%**
Total Geo	**5.9**	**96.4**	**200.0**

Increased Electrification + Education Benefits results

In the case of the Increased Education Benefits, we estimated additional benefits of education that result in higher labor productivity. For this, we calculated the number of impacted people and used the education rate of return of 12 percent (Makarov et al. 2020) to calculate the increased average productivity of affected workers. Tables A2-10–A2-12 provide the results for this setting under different costs of geothermal.

Table A2-10. Impacts of expanding geothermal in the Increased Electrification+Education Setting with the high cost of geothermal

	Benchmark	**Reference**		**1% Geothermal**		**5% Geothermal**		**10% Geothermal**		**15% Geothermal**	
	2014	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**
GDP (billion 2014$)	843.2	1985.8	3571.9	1998.7	3602.6	2052.4	3711.4	2122.9	3856.3	2197.8	4012.5
Emissions (mmtCO2e)	733.9	1483.6	2365.1	1483.1	2418.9	1485.9	2416.0	1487.0	2411.7	1478.8	2406.7
Labor in Elec Sector ($)	0.1	0.3	0.9	0.4	1.0	0.6	1.4	1.0	2.1	1.3	2.8
Labor in Coal Elec ($)	0.05	0.22	0.62	0.22	0.60	0.22	0.59	0.22	0.57	0.21	0.55
Labor in Geo Elec ($)	0.01	0.00	0.00	0.06	0.12	0.31	0.61	0.66	1.27	1.03	1.99
Electricity (TWh)	222.3	684.1	1022.4	687.7	1078.6	714.2	1109.0	744.8	1149.2	762.6	1192.0
Coal	120.6	423.4	631.9	421.8	666.2	424.6	657.6	424.1	645.9	412.5	633.1
Gas	57.9	194.2	314.9	193.3	326.0	194.5	320.5	193.7	313.0	186.8	304.8
Hydro	15.2	48.5	65.2	48.4	65.2	48.5	65.2	48.5	65.2	48.5	65.2
Oil	22.7	18.1	10.3	17.3	10.3	10.5	10.3	3.1	10.3		10.3
Geo-New	5.9		0.0	6.9	10.7	36.1	55.3	75.3	114.7	114.8	178.5
% Geo-New	**3%**	**0%**	**0%**	**1%**	**1%**	**5%**	**5%**	**10%**	**10%**	**15%**	**15%**
Total Geo	**5.9**	**5.9**	**5.9**	**12.8**	**16.6**	**42.0**	**61.2**	**81.2**	**120.6**	**120.7**	**184.4**

Table A2-11. Impacts of expanding geothermal in the Increased Electrification+Education Setting with the base cost of geothermal

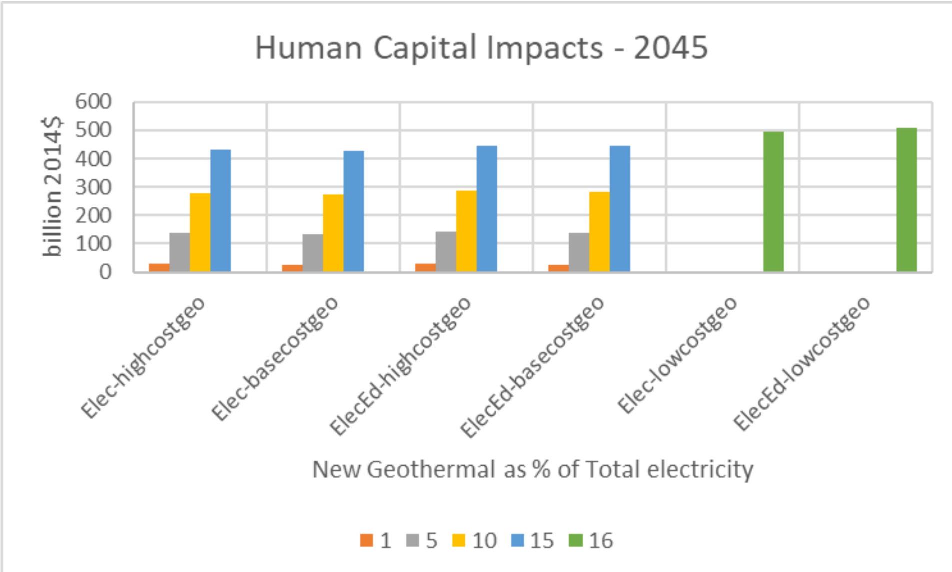
	Benchmark	Reference		1% Geothermal		5% Geothermal		10% Geothermal		15% Geothermal	
	2014	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**
GDP (billion 2014$)	843.2	1985.8	3576.5	1999.1	3602.9	2054.2	3713.1	2126.9	3860.2	2204.0	4018.8
Emissions (mmtCO2e)	733.9	1483.4	2419.6	1482.9	2419.5	1483.9	2418.9	1485.3	2417.4	1483.5	2415.2
Labor in Elec Sector ($)	0.1	0.3	0.8	0.4	0.9	0.5	1.1	0.7	1.5	0.9	1.8
Labor in Coal Elec ($)	0.05	0.22	0.60	0.22	0.60	0.22	0.59	0.22	0.59	0.22	0.58
Labor in Geo Elec ($)	0.01	0.00	0.00	0.03	0.06	0.16	0.31	0.34	0.65	0.55	1.02
Electricity (TWh)	222.3	684.3	1071.7	689.2	1080.4	715.8	1118.6	752.2	1170.1	784.8	1226.0
Coal	120.6	423.2	668.1	422.2	667.3	422.3	662.9	422.9	656.7	421.7	649.5
Gas	57.9	194.1	327.3	193.5	326.7	193.5	324.1	193.8	320.3	192.8	315.9
Hydro	15.2	48.5	65.2	48.5	65.2	48.5	65.2	48.5	65.2	48.5	65.2
Oil	22.7	18.1	10.3	18.1	10.3	15.2	10.3	10.4	10.3	2.9	10.3
Geo-New	5.9	0.4	0.8	6.9	10.8	36.2	56.0	76.7	117.4	119.0	185.1
% Geo-New	**3%**	**0%**	**0%**	**1%**	**1%**	**5%**	**5%**	**10%**	**10%**	**15%**	**15%**
Total Geo	**5.9**	**6.3**	**6.7**	**12.8**	**16.7**	**42.1**	**61.9**	**82.6**	**123.3**	**124.9**	**191.0**

Table A2-12. Impacts of expanding geothermal in the Increased Electrification+Education Setting with the low cost of geothermal

	Benchmark	Reference	
	2014	**2030**	**2045**
GDP (billion 2014$)	843.2	2159.5	4088.3
Emissions (mmtCO2e)	733.9	1483.2	2421.1
Labor in Elec Sector ($)	0.1	0.5	1.4
Labor in Coal Elec ($)	0.05	0.21	0.59
Labor in Geo Elec ($)	0.01	0.20	0.60
Electricity (TWh)	222.3	768.5	1222.3
Coal	120.6	420.4	661.5
Gas	57.9	192.9	322.6
Hydro	15.2	50.1	38.1
Oil	22.7	14.3	6.0
Geo-New	5.9	90.8	194.1
% Geo-New	**3%**	**12%**	**16%**
Total Geo	**5.9**	**96.7**	**200.0**

Educational benefits further increase the positive impacts of geothermal. When the share of geothermal is pushed to 15 percent, they add about $12 billion in 2030 and about $14 billion in 2045. In the *lowcostgeo* scenario, the corresponding increase in 2045 is about $16 billion. Figure A2-3 provides an illustration of the total human capital benefits of expanded geothermal (from electrification and education) in 2045. When the share of geothermal is pushed to 15 percent, human capital benefits reach about $220 billion in 2030 and about $445 billion in 2045. The human capital benefits in the scenario of low-cost geothermal reach about $510 billion in 2045.

Figure A2-3. Improved human capital impacts with expanded geothermal electricity production in Indonesia in 2045



Health Impacts results

Boosting levels of geothermal power not only helps mitigate emissions and climate change but also reduces local air pollution. Quantifying the extent to which this approach improves air quality could help decision makers better assess the pros and cons of implementing policies such as promoting geothermal. As discussed above, here we apply an aggregate approach for quantification of health impacts, where the value of health benefits equals 8 cents for each kilowatt hour (kWh) of geothermal electricity. The value quantifies the benefits of reducing premature mortality from exposure to $PM_{2.5}$.

$PM_{2.5}$ stands for particulate matter, which is a mixture of solid particles and liquid droplets in the air with diameters of 2.5 micrometers and smaller. The particles form in the atmosphere as a result of complex reactions of chemicals such as SO_2, NO_X, CO, and black carbon, which are pollutants emitted from power plants, industries and automobiles. When inhaled, $PM_{2.5}$ causes serious health problems, including premature mortality.

Impacts at a particular location depend on numerous factors, including weather and climatic conditions that affect concentrations of pollutants. Health-impact evaluations also rely on concentration-response functions that also entail ranges of uncertainty. Finally, monetization of health impacts is usually based on a country-specific value of statistical life approach. Hence, our calculation should be treated as illustrative. For location-specific results, a simplified or full-scale air pollution model should be employed that would simulate the formation of secondary $PM_{2.5}$ and long-range spatially resolved transport of pollution particles.

We do not estimate the impacts of the remaining air pollution, rather our calculation shows the health-related impacts of reduction in air pollution due to increased levels of geothermal power generation. Tables A2-13–A2-15 provide the results when health benefits are considered.

Table A2-13. Impacts of expanding geothermal considering the Health Impacts with the high cost of geothermal

	Benchmark	Reference		1% Geothermal		5% Geothermal		10% Geothermal		15% Geothermal	
	2014	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**
GDP (billion 2014$)	843.7	1986.3	3572.4	1986.4	3572.9	1986.6	3575.0	1986.9	3577.6	1986.9	3580.3
Emissions (mmtCO2e)	733.9	1483.6	2365.1	1482.9	2363.0	1483.9	2354.3	1478.3	2342.7	1460.7	2329.9
Labor in Elec Sector ($)	0.1	0.3	0.9	0.4	1.0	0.6	1.4	0.9	2.0	1.3	2.6
Labor in Coal Elec ($)	0.05	0.22	0.62	0.22	0.61	0.22	0.59	0.21	0.57	0.20	0.54
Labor in Geo Elec ($)	0.01	0.00	0.00	0.06	0.11	0.31	0.58	0.64	1.19	0.99	1.84
Electricity (TWh)	222.3	684.1	1022.4	688.3	1027.4	710.5	1048.1	730.5	1074.5	732.4	1101.2
Coal	120.6	423.4	631.9	422.7	628.6	424.8	615.0	418.3	596.9	396.3	577.4
Gas	57.9	194.2	314.9	193.7	313.0	194.5	305.1	190.4	294.6	177.9	283.0
Hydro	15.2	48.5	65.2	48.5	65.2	48.5	65.2	48.5	65.2	48.4	65.2
Oil	22.7	18.1	10.3	16.6	10.3	7.3	10.3	0.3	10.3		10.3
Geo-New	5.9		0.0	6.9	10.2	35.5	52.4	73.0	107.5	109.9	165.2
% Geo-New	**3%**	**0%**	**0%**	**1%**	**1%**	**5%**	**5%**	**10%**	**10%**	**15%**	**15%**
Total Geo	**5.9**	**5.9**	**5.9**	**12.8**	**16.1**	**41.4**	**58.3**	**78.9**	**113.4**	**115.8**	**171.1**

Table A2-14. Impacts of expanding geothermal considering the Health Impacts with the base cost of geothermal

	Benchmark	Reference		1% Geothermal		5% Geothermal		10% Geothermal		15% Geothermal	
	2014	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**
GDP (billion 2014$)	843.7	1986.3	3577.1	1986.7	3577.8	1988.3	3581.2	1990.5	3585.6	1992.5	3590.3
Emissions (mmtCO2e)	733.9	1483.4	2419.6	1482.4	2417.7	1482.1	2409.4	1480.1	2398.3	1469.8	2386.1
Labor in Elec Sector ($)	0.1	0.3	0.8	0.4	0.9	0.5	1.1	0.6	1.4	0.8	1.7
Labor in Coal Elec ($)	0.05	0.22	0.60	0.22	0.60	0.22	0.58	0.22	0.56	0.21	0.54
Labor in Geo Elec ($)	0.01	0.00	0.00	0.03	0.06	0.15	0.30	0.32	0.63	0.52	0.97
Electricity (TWh)	222.3	684.3	1071.7	688.5	1077.8	712.3	1104.8	742.2	1140.3	761.3	1175.5
Coal	120.6	423.2	668.1	422.1	665.6	422.8	654.4	421.7	639.4	411.5	622.1
Gas	57.9	194.1	327.3	193.5	325.9	193.8	319.7	193.1	311.3	187.1	301.7
Hydro	15.2	48.5	65.2	48.5	65.2	48.5	65.2	48.5	65.2	48.5	65.1
Oil	22.7	18.1	10.3	17.5	10.3	11.7	10.3	4.8	10.3	0.0	10.3
Geo-New	5.9	0.4	0.8	6.9	10.8	35.6	55.2	74.2	114.0	114.2	176.3
% Geo-New	**3%**	**0%**	**0%**	**1%**	**1%**	**5%**	**5%**	**10%**	**10%**	**15%**	**15%**
Total Geo	**5.9**	**6.3**	**6.7**	**12.8**	**16.7**	**41.5**	**61.1**	**80.1**	**119.9**	**120.1**	**182.2**

Table A2-15. Impacts of expanding geothermal considering the Health Impacts with the low cost of geothermal

	Benchmark	Reference	
	2014	**2030**	**2045**
GDP (billion 2014$)	843.7	1993.3	3594.0
Emissions (mmtCO2e)	733.9	1478.3	2387.1
Labor in Elec Sector ($)	0.1	0.3	0.8
Labor in Coal Elec ($)	0.05	0.22	0.60
Labor in Geo Elec ($)	0.01	0.00	0.00
Electricity (TWh)	222.3	756.2	1175.5
Coal	120.6	420.6	629.6
Gas	57.9	192.8	306.1
Hydro	15.2	48.5	39.4
Oil	22.7	6.4	6.2
Geo-New	5.9	87.8	194.1
% Geo-New	**3%**	**12%**	**17%**
Total Geo	**5.9**	**93.7**	**200.0**

Figures A2-4 and A2-5 provide an illustration of health benefits of expanded geothermal in 2030 and 2045. When the share of geothermal is pushed to 15 percent, health benefits reach about $10 billion in 2030 and about $14 billion in 2045. Not shown in the figures are the results for the *lowcostgeo* scenario, where the 2030 impacts with 12 percent of geothermal share are about $7.5 billion and the 2040 impacts with 17 percent of geothermal share are $16 billion.

Figure A2-4. Improved health impacts with expanded geothermal electricity production in Indonesia in 2030

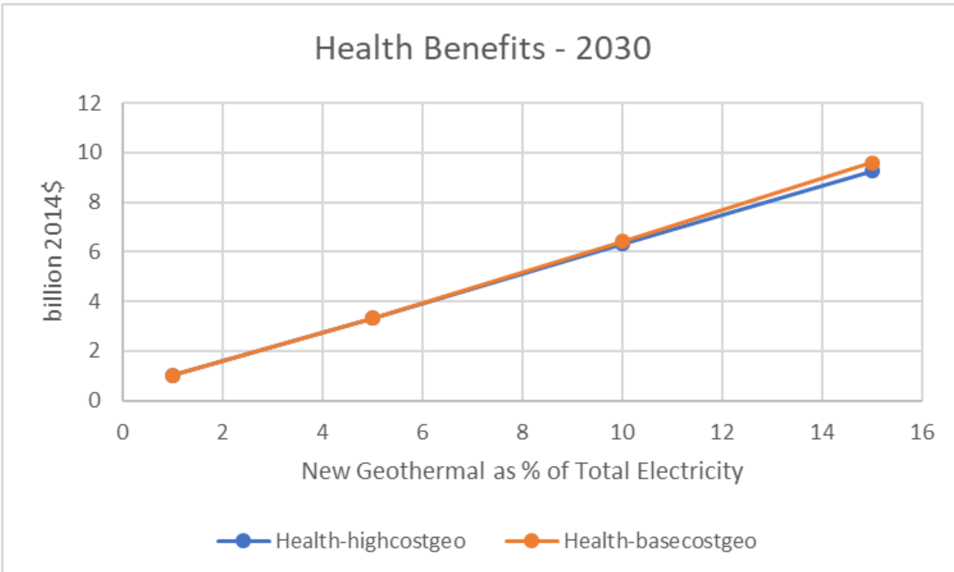
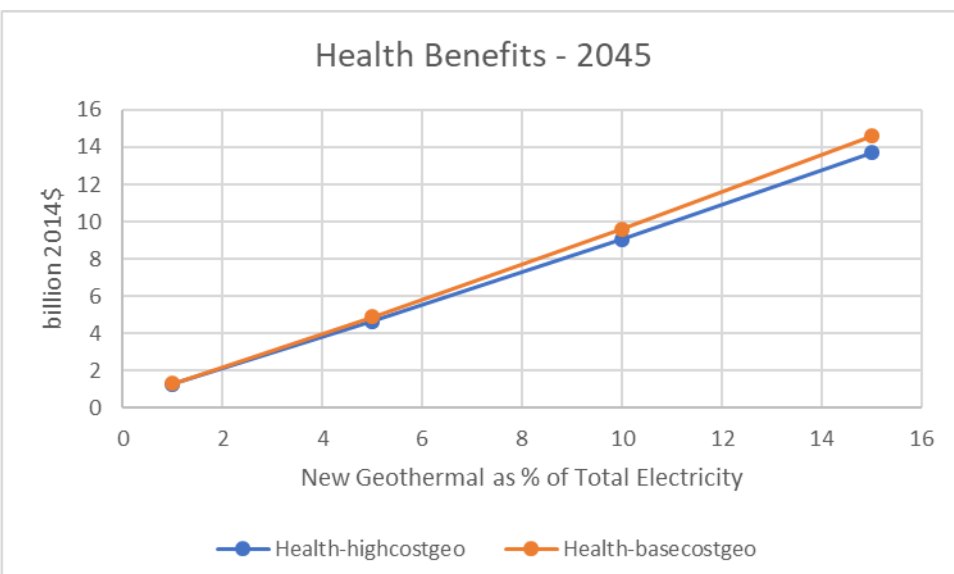


Figure A2-5. Improved health impacts with expanded geothermal electricity production in Indonesia in 2045



Combined impacts results

We have combined all impact channels in the scenario ALL. Tables A2-16–A2-18 provide the results for the combined scenario.

Table A2-16. Combined impacts of expanding geothermal with the high cost of geothermal

	Benchmark	**Reference**		**1% Geothermal**		**5% Geothermal**		**10% Geothermal**		**15% Geothermal**	
	2014	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**
GDP (billion 2014$)	843.7	1986.3	3572.4	1999.7	3603.9	2055.7	3716.3	2129.4	3866.0	2207.5	4027.3
Emissions (mmtCO2e)	733.9	1483.6	2365.1	1483.1	2418.9	1485.9	2416.0	1487.0	2411.7	1478.8	2406.7
Labor in Elec Sector ($)	0.1	0.3	0.9	0.4	1.0	0.6	1.4	1.0	2.1	1.3	2.8
Labor in Coal Elec ($)	0.05	0.22	0.62	0.22	0.60	0.22	0.59	0.22	0.57	0.21	0.55
Labor in Geo Elec ($)	0.01	0.00	0.00	0.06	0.12	0.31	0.61	0.66	1.27	1.03	1.99
Electricity (TWh)	222.3	684.1	1022.4	687.7	1078.6	714.2	1109.0	744.8	1149.2	762.6	1192.0
Coal	120.6	423.4	631.9	421.8	666.2	424.6	657.6	424.1	645.9	412.5	633.1
Gas	57.9	194.2	314.9	193.3	326.0	194.5	320.5	193.7	313.0	186.8	304.8
Hydro	15.2	48.5	65.2	48.4	65.2	48.5	65.2	48.5	65.2	48.5	65.2
Oil	22.7	18.1	10.3	17.3	10.3	10.5	10.3	3.1	10.3		10.3
Geo-New	5.9		0.0	6.9	10.7	36.1	55.3	75.3	114.7	114.8	178.5
% Geo-New	**3%**	**0%**	**0%**	**1%**	**1%**	**5%**	**5%**	**10%**	**10%**	**15%**	**15%**
Total Geo	**5.9**	**5.9**	**5.9**	**12.8**	**16.6**	**42.0**	**61.2**	**81.2**	**120.6**	**120.7**	**184.4**

Table A2-17. Combined impacts of expanding geothermal with the base cost of geothermal

	Benchmark	**Reference**		**1% Geothermal**		**5% Geothermal**		**10% Geothermal**		**15% Geothermal**	
	2014	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**
GDP (billion 2014$)	843.7	1986.3	3577.1	2000.1	3604.3	2057.6	3718.1	2133.5	3870.0	2214.0	4034.1
Emissions (mmtCO2e)	733.9	1483.4	2419.6	1482.9	2419.5	1483.9	2418.9	1485.3	2417.4	1483.5	2415.2
Labor in Elec Sector ($)	0.1	0.3	0.8	0.4	0.9	0.5	1.1	0.7	1.5	0.9	1.8
Labor in Coal Elec ($)	0.05	0.22	0.60	0.22	0.60	0.22	0.59	0.22	0.59	0.22	0.58
Labor in Geo Elec ($)	0.01	0.00	0.00	0.03	0.06	0.16	0.31	0.34	0.65	0.55	1.02
Electricity (TWh)	222.3	684.3	1071.7	689.2	1080.4	715.8	1118.6	752.2	1170.1	784.8	1226.0
Coal	120.6	423.2	668.1	422.2	667.3	422.3	662.9	422.9	656.7	421.7	649.5
Gas	57.9	194.1	327.3	193.5	326.7	193.5	324.1	193.8	320.3	192.8	315.9
Hydro	15.2	48.5	65.2	48.5	65.2	48.5	65.2	48.5	65.2	48.5	65.2
Oil	22.7	18.1	10.3	18.1	10.3	15.2	10.3	10.4	10.3	2.9	10.3
Geo-New	5.9	0.4	0.8	6.9	10.8	36.2	56.0	76.7	117.4	119.0	185.1
% Geo-New	**3%**	**0%**	**0%**	**1%**	**1%**	**5%**	**5%**	**10%**	**10%**	**15%**	**15%**
Total Geo	**5.9**	**6.3**	**6.7**	**12.8**	**16.7**	**42.1**	**61.9**	**82.6**	**123.3**	**124.9**	**191.0**

Table A2-18. Combined impacts of expanding geothermal with the low cost of geothermal

	Benchmark	Reference	
	2014	**2030**	**2045**
GDP (billion 2014$)	843.7	2167.2	4104.3
Emissions (mmtCO2e)	733.9	1483.2	2421.1
Labor in Elec Sector ($)	0.1	0.3	0.8
Labor in Coal Elec ($)	0.05	0.22	0.60
Labor in Geo Elec ($)	0.01	0.00	0.00
Electricity (TWh)	222.3	768.5	1222.3
Coal	120.6	420.4	661.5
Gas	57.9	192.9	322.6
Hydro	15.2	50.1	38.1
Oil	22.7	14.3	6.0
Geo-New	5.9	90.8	194.1
% Geo-New	**3%**	**12%**	**16%**
Total Geo	**5.9**	**96.7**	**200.0**

Our results show substantial benefits of expanding geothermal energy in Indonesia. We also show that quantifying the effects of increased electrification, increased education and air pollution health impacts are important for decision making related to support for geothermal project development.

Job results

In addition to economy-wide impacts of expanding geothermal energy, we provide a simplified estimate of job impacts in terms of workers for geothermal operations and sustained geothermal construction. We based our calculation on two sources. The U.S. Bureau of Labor Statistics (2012)[56] reports for the U.S. that developing a 50 MW geothermal plant requires between 697 and 862 workers, including geologists, hydrologists, civil engineers, electrical engineers, drilling crews, and construction workers. A typical construction time for a 50 MW plant is 2 years, which results in 7.8 job years/MW for an average number of 780 workers in a project construction. This number is consistent with the number for the U.S. (6.8 job years/MW) from a globally focused study by Rutovitz et al. (2015)[57] that provides the number of jobs in operation and construction of geothermal per kW installed capacity. For the number of jobs in an operating geothermal plant, Rutovitz et al. (2015) reports 0.4 jobs/MW.

While wages in the U.S. and Indonesia differ, the requirements for particular qualified personnel can be similar for operating drilling equipment and other machinery and engineering tasks. One may argue that the number of workers may differ due to the differences in the marginal rate of substitution between labor and capital in the U.S. and Indonesia. Indeed, Rutovitz et al (2015) uses regional adjustment factors for scaling the number of jobs between the U.S. and Asia. These scaling factors are 1.9 for 2030 and 1.4 for 2045. Based on these simplified assumptions, in Table A2-19 we provide the results for jobs in geothermal operations in different scenarios. To estimate the number of jobs in the geothermal construction industry, we used 6.8 Job Years/MW for geothermal and regional adjustment factors (between the U.S. and Asia) of 1.9 for 2030 and 1.4 for 2045 from Rutovitz et al (2015). We adjusted the total number for the number of years to reach a particular target share of geothermal generation. In Table A2-20 we report the annual numbers (for 2030 and 2045) of long-term jobs in the geothermal construction sector in Indonesia. The numbers for the lowcostgeo scenario are comparable with the results for the 15 percent share in Tables A2-19–A2-20.

Table A2-19. Number of jobs in geothermal operations with expanded geothermal capacity

Jobs in Geothermal operations								
	2030	**2045**	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**
	1% Geothermal		**5% Geothermal**		**10% Geothermal**		**15% Geothermal**	
(1)Base-highcostgeo	748	820	3858	4191	7930	8597	11928	13216
(1)Base-basecostgeo	750	861	3870	4417	8056	9119	12394	14108
(2)Elec-highcostgeo	750	859	3916	4421	8153	9160	12418	14241
(2)Elec-basecostgeo	752	863	3929	4474	8298	9377	12872	14760
(3)ElecEd-highcostgeo	749	859	3923	4424	8177	9175	12465	14278
(3)ElecEd-basecostgeo	752	863	3935	4478	8324	9395	12923	14806
(4)Health-highcostgeo	748	820	3858	4191	7930	8597	11928	13216
(4)Health-basecostgeo	750	861	3870	4417	8056	9119	12394	14108
(5)All-highcostgeo	749	859	3923	4424	8177	9175	12465	14278
(5)All-basecostgeo	752	863	3935	4478	8324	9395	12923	14806

Table A2-20. Number of sustained jobs per year in geothermal construction with expanded geothermal capacity

Jobs in Geothermal construction								
	2030	**2045**	**2030**	**2045**	**2030**	**2045**	**2030**	**2045**
	1% Geothermal		**5% Geothermal**		**10% Geothermal**		**15% Geothermal**	
(1)Base-highcostgeo	1271	929	6559	4749	13481	9743	20278	14978
(1)Base-basecostgeo	1275	976	6578	5006	13696	10335	21070	15989
(2)Elec-highcostgeo	1275	973	6658	5010	13860	10381	21111	16139
(2)Elec-basecostgeo	1279	978	6679	5071	14107	10627	21883	16728
(3)ElecEd-highcostgeo	1273	973	6668	5014	13900	10398	21191	16182
(3)ElecEd-basecostgeo	1279	978	6690	5075	14152	10648	21969	16780
(4)Health-highcostgeo	1271	929	6559	4749	13481	9743	20278	14978
(4)Health-basecostgeo	1275	976	6578	5006	13696	10335	21070	15989
(5)All-highcostgeo	1273	973	6668	5014	13900	10398	21191	16182
(5)All-basecostgeo	1279	978	6690	5075	14152	10648	21969	16780

Summary of GDP impacts

Supporting geothermal development may lead to sizeable impacts on Indonesia's GDP. Table A2-21 reports GDP levels in constant 2014 U.S. dollars. With a larger share of new geothermal in total electricity generation, impacts on GDP grow.

Table A2-21. Indonesia's GDP (billion 2014$) in different scenarios

	2030	2045	2030	2045	2030	2045	2030	2045
	1% Geothermal		5% Geothermal		10% Geothermal		15% Geothermal	
(1)Base-highcostgeo	1985.3	3571.6	1983.3	3570.3	1980.5	3568.5	1977.6	3566.6
(1)Base-basecostgeo	1985.7	3576.5	1985.0	3576.3	1984.1	3576.0	1982.9	3575.7
(2)Elec-highcostgeo	1998.1	3601.9	2048.6	3707.2	2115.0	3847.5	2185.4	3998.7
(2)Elec-basecostgeo	1998.4	3602.3	2050.4	3708.9	2119.0	3851.4	2191.6	4005.0
(3)ElecEd-highcostgeo	1998.7	3602.6	2052.4	3711.4	2122.9	3856.3	2197.8	4012.5
(3)ElecEd-basecostgeo	1999.1	3602.9	2054.2	3713.1	2126.9	3860.2	2204.0	4018.8
(4)Health-highcostgeo	1986.4	3572.9	1986.6	3575.0	1986.9	3577.6	1986.9	3580.3
(4)Health-basecostgeo	1986.7	3577.8	1988.3	3581.2	1990.5	3585.6	1992.5	3590.3
(5)All-highcostgeo	1999.7	3603.9	2055.7	3716.3	2129.4	3866.0	2207.5	4027.3
(5)All-basecostgeo	2000.1	3604.3	2057.6	3718.1	2133.5	3870.0	2214.0	4034.1

In Table A2-22**,** we provide a summary of GDP impacts for all scenarios and settings (calculated relative to the corresponding Reference case). As mentioned, without a proper estimation of benefits from electrification, education and health, impacts on GDP from expanding geothermal are negative. With these benefits considered, the largest positive contribution to GDP is from expanded electrification (under the assumption that all geothermal power is used for increased access to electricity in Indonesia). Improved labor productivity from increased education provides further benefits to GDP. Health benefits from reduced air pollution are relatively small but also valuable in terms of adding to GDP.

When all channels for benefits are combined, GDP in Indonesia is higher by about 9–11 percent in 2030 and by about 13–14 percent in 2045 when geothermal power has a share of 15 percent in the total electricity generation in Indonesia or geothermal cost is low. Geothermal energy represents a good option for Indonesia to achieve a comprehensive approach to energy development and decarbonization. Geothermal energy provides a solution to power generation. In addition, it creates substantial benefits to economic development in Indonesia.

In the scenarios considered in this report, we scale-up geothermal power generation at the expense of other renewable technologies. Energy transition in Indonesia based on renewable technologies like wind and solar would have similar positive GDP impacts. The relatively limited options for solar and wind in Indonesia make geothermal an attractive option to bring these economic benefits to Indonesia. Further, where these technologies are available, geothermal has the distinct advantage of providing baseload power that is not subject to the same degree of intermittency as wind and solar. Another potential option in Indonesia is hydropower (including pumped hydro). We have not explored hydropower expansion in this report, and we note that a proper assessment of hydropower requires project-specific evaluations of environmental impacts on biodiversity, land use, and natural habitats in the dam areas.

Table A2-22. Impact on Indonesia's GDP in different scenarios: GDP % Change Relative to Reference

	2030	2045	2030	2045	2030	2045	2030	2045	2030	2045
	1% Geothermal		**5% Geothermal**		**10% Geothermal**		**15% Geothermal**			
(1)Base-highcostgeo	0.0	-0.1	-0.1	-0.2	-0.3	-0.2	-0.4	-0.3		
(1)Base-basecostgeo	0.0	0.0	0.0	0.0	-0.1	0.0	-0.1	0.0		
(1)Base-lowcostgeo									0.0	0.0
(2)Elec-highcostgeo	0.6	0.7	3.2	3.7	6.5	7.6	10.1	11.8		
(2)Elec-basecostgeo	0.6	0.7	3.3	3.7	6.7	7.7	10.4	12.0		
(2)Elec-lowcostgeo									8.3	13.9
(3)ElecEd-highcostgeo	0.7	0.7	3.4	3.8	6.9	7.8	10.7	12.2		
(3)ElecEd-basecostgeo	0.7	0.7	3.4	3.8	7.1	7.9	11.0	12.4		
(3)ElecEd-lowcostgeo									8.7	14.3
(4)Health-highcostgeo	0.0	-0.1	0.0	0.0	0.1	0.0	0.1	0.1		
(4)Health-basecostgeo	0.0	0.0	0.1	0.1	0.2	0.3	0.3	0.4		
(4)Health-lowcostgeo									0.4	0.5
(5)All-highcostgeo	0.7	0.8	3.5	3.9	7.2	8.1	11.2	12.6		
(5)All-basecostgeo	0.7	0.8	3.6	4.0	7.4	8.2	11.5	12.8		
(5)All-lowcostgeo									9.1	14.8

Results for individual geothermal projects

Based on the results that we have obtained for different shares of geothermal generation, we can provide a rough evaluation of the impacts from developing individual geothermal projects. Care should be taken in scaling the economy-wide results to the level of individual projects as local conditions may differ.

As an illustration, we consider two projects. The Ulubelu project (units 3 and 4) is in Sumatra Island (Western Indonesia) in the province of Lampung. It envisions two 55 MW plants. Scaling the economy-wide results to the capacity of 110 MW results in the following impacts of the project: 84 added jobs during operation of the project; 142 added long-term jobs in the geothermal construction sector; 1,421 added jobs in project construction (assuming a two-year construction period); $114 million in health benefits from reduced air pollution; 2 Mt CO_2 reduction of economy-wide emissions over 30 years; $1.4 billion in human capital impacts if power is used for increased electrification (Channel A); and $1.5 billion in human capital impacts if power is used for increased electrification and education (Channel B).

The Lahendong project (units 5 and 6) is in North Sulawesi (Northern Indonesia) in the Minahasa area. It envisions two 20 MW plants. Scaling the economy-wide results to the capacity of 40 MW results in the following impacts of the project: 30 added jobs in the operation of the project; 52 added long-term jobs in geothermal construction sector; 517 added jobs in project construction (assuming a two-year construction period); $42 million in health benefits from reduced air pollution; 0.75 Mt CO_2 reduction in economy-wide emissions over 30 years; $0.52 billion in human capital impacts if power is used for increased electrification; and $0.54 billion in human capital impacts if power is used for increased electrification and education.

In a similar fashion, the results for a 1 GW project can be scaled as follows: 760 added jobs in the operation of the project; 1,300 added long-term jobs in the geothermal construction sector; about 12,000 added jobs in project construction (assuming a two-year construction period); $1,040 million in health benefits from reduced air pollution; 20 Mt CO_2 reduction in economy-wide emissions over 30 years; $13 billion in human capital impacts if power is used for increased electrification in the areas without previous reliable energy access; and $13.5 billion in human capital impacts if power is used for increased electrification and education.

Endnotes

[1] OECD. (2021). Economic Outlook – Indonesia

[2] World Bank. (2015). Indonesia's Rising Divide

[3] OECD. (2021). OECD Economic Survey of Indonesia

[4] IHS Markit (2021) Indonesia's greener electricity supply business plan – 2021 RUPTL

[5] CIF (2022) Indonesia; CIF (2015) Revised Investment Plan; IFC (2017) Amendment to the CTF Investment Plan

[6] The key stakeholders, including geothermal developers, are listed in Table 2.

[7] The Private Sector Geothermal Project (PSGP) led by the Asian Development Bank was placed out of scope for close investigation in this case study due to its longer lead times to generate evidence. This includes the following private sector projects: Sarulla Geothermal Power Generation Project (CIF funding: $80 million), Muara Laboh Geothermal Power Project (CIF funding: $19.25 million), Rantau Dedap Geothermal Power Project Phase 1 (CIF funding: $50 million) and Phase 2 (CIF funding: $50 million).

[8] The CGE modeling estimates the impacts of geothermal investments at a national scale. The benefits of the CIF projects were interpolated from the CGE modeling results. The modeling was based on a planned installed capacity of 2,120 MW, instead of the 1,815 MW, because the evaluation team included installed capacity for a project that was canceled.

[9] E.g., Campen et al. (2017) Analysis of the New Indonesian Geothermal Tariff System

[10] Interview with local government in Lahendong North Sulawesi

[11] Interview with PGE

[12] Geo Dipa Energi (2021) Government Drilling Project.

[13] Geo Dipa Energi (2020) Impacts and Benefits of Climate Investment Funds (CIF) in the Dieng Unit 2 Geothermal Power Plant Project

[14] Interview with PGE

[15] 2030 is the most reliable timeline for capacity additions and 5% added share of geothermal in the power mix is closest to the most likely scenario in the model, provided that Indonesia meets its targets as set out in the Supply Plan. The 5% share reflects current (2.1 GW) and planned additions (3.4 GW) of geothermal capacity, in proportion to the existing total power generation capacity of 63 GW and planned new capacity of 41 GW in 2030.

[16] The 2,120 MW of installed capacity from CIF-funded projects differs from the 1,815 MW listed earlier in the report because the evaluation team included installed capacity for a project that was canceled.

[17] The $107 million is economic output/income; this value was interpolated from the GDP impacts estimated with the CGE model. In principle, the annual value will change over time, but for simplicity it can be approximated by the project duration (estimated at 30 years). Note this is the maximum annual benefit once all plants are online. In reality, the annual benefit will ramp up as the plants are switched on and ramp down as they are decommissioned.

[18] Interview with Masarang Foundation

[19] Interview with the Head of Lahendong Village

[20] Richter (2022) Sustainable tourism on Flores Geothermal Island, Indonesia

[21] Interview with Minahasa Local Agency for Environment

[22] This enables stakeholders to raise grievances with the investor and seek redress when they perceive a negative impact arising from the investor's activities – WB (2022) Grievance Redress Mechanisms

[23] Geo Dipa Energi (2021) *Government Drilling Project – Review of Benefits of CIF Funds for Government Drilling Project*
[24] The Wae Sano geothermal site faced opposition from a divided local community, with different opinions on geothermal exploration and production. The local stance was impacted by various factors, e.g., the opinion of a community leader, who was in favor of geothermal development. Nonetheless, this highlights the importance of respectful stakeholder dialogue, and protection of land rights and the rights of indigenous people.
[25] World Bank project documents for the GCEIP
[26] World Bank project documents for the GEUDP and GREM project
[27] This argument was also brought forward during the interview with the World Bank Task Team Lead.
[28] Actors in different steering committees include the MEMR, the MoF and the MoEF; and the Ministry of State-owned Enterprises, PLN, PGE and Geo Dipa Energi – Richter (2021) Team formed to accelerate work on state geothermal holding
[29] Interview with MEMR
[30] PROFOR (2020) Environmental and Social Impacts of Geothermal Development in Conservation Forest Areas in Indonesia
[31] Interview with PGE
[32] Interview with PGE
[33] Funds flow from CIF to the MoF and further to the MoF's special entity disbursing the funds to developers.
[34] The Diplomat (2021) A Turning Point for Renewable Energy in Indonesia
[35] It is expected that geothermal development will accelerate with the Indonesian Supply Plan.
[36] Kahkonen (2021) Why women matter for Indonesia's economic recovery
[37] A portfolio approach means exploring several wells (a portfolio of wells) due to uncertainty in finding enough resources.
[38] The concept of revenue recycling is widely known and recognized in taxation policy, where revenues gained from taxes can be re-directed towards sustainable investments in the sector they are derived from or spent on vulnerable societal groups where the socioeconomic impact of tax spending is relatively higher.
[39] This appendix was authored by Jennifer Morris, Sergey Paltsev, Brent Boehlert, and Ken Strzepek.
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[52] See https://climateactiontracker.org/countries/indonesia/.
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[54] Morris, J., J. Farrell, H. Kheshgi, H. Thomann, H. Chen, S. Paltsev and H. Herzog (2019). Representing the Costs of Low-Carbon Power Generation in Multi-region Multi-sector Energy-Economic Models. *International Journal of Greenhouse Gas Control*, 87, 170-187.
Morris, J., S. Paltsev, and A. Ku (2019). Impacts of China's emissions trading schemes on deployment of power generation with carbon capture and storage. *Energy Economics*, 81, 848-858.
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7. Indonesia Light-Touch Case Study: Development Impacts of Sustainable Forest Management

Project Details	Funding
Project Names: Community-Focused Investments to Address Deforestation and Forest Degradation (FIP-1) Promoting Sustainable Community-Based Natural Resource Management (CBNRM) and Institutional Development Strengthening Rights and Economies of Adat and Local Communities (DGM-1) **Country:** Indonesia **CIF Program Area:** Forest Investment Program (FIP) **Bank approval:** September 2016 (FIP-1); April 2016 (CBNRM); May 2017 (DGM-1) **Effective since:** December 2016 (FIP-1); May 2016 (CBNRM); June 2017 (DGM-1) **Expected closing:** June 2023 (FIP-1); December 2022 (CBNRM); November 2022 (DGM-1) **MDBs:** Asian Development Bank (ADB), World Bank	**Total Value:** US$18.7 million (FIP-1); US$22.42 million (CBNRM); US$6.3 million (DGM-1) **CIF:** US$17 million (FIP-1); US$17.35 million (CBNRM); US$6.3 million (DGM-1) **Instrument type:** Grants **Sector:** Public

Key Highlights

- The CIF Sustainable Forest Management (SFM) projects aim to address deforestation and forest degradation in Indonesia while reducing emissions, strengthening institutional and local capacity for decentralized forest management, and improving livelihoods in targeted areas.
- This case study focuses on three CIF Forest Investment Program (FIP) projects in Indonesia with a total CIF investment of US$40.6 million.

Topline Findings on Development Impacts

- **Market development:** Improved access to markets and thus the creation of economic and employment opportunities is among the main development impacts (DIs) of these interventions, leading to new activities and alternative sources of income.
- **Community engagement:** Community engagement in SFM and social inclusion have also been significantly improved throughout the projects.
- **Benefits to local stakeholders:** A total of nearly 113,000 people are expected to benefit from the three projects, who are to a large extent customary law communities and Indigenous Peoples and local communities (IPLCs).
- **Women's empowerment:** More than 30,000 women are expected to benefit from the CIF-SFM projects. Besides contributing to economic empowerment, the projects also enhance women's involvement in conflict resolution and strengthen the enabling conditions to ensure their sustained participation.

- SFM measurement and reporting can be improved by using metrics that better reflect the DIs of the projects, in particular impacts on women. According to interviewees, the reported DIs for women are generally underestimated.

Climate Investment Context and Overview

Governments around the world are increasingly engaging rural communities in forest management to address issues such as deforestation and forest degradation, biodiversity losses, and climate change.[1] In Indonesia, national and subnational initiatives have emerged to curb deforestation, including community-based and social forestry programs.[2] Indonesia's current Long-Term Strategy for Low Carbon and Climate Resilience 2050 (LTS-LCCR), published in 2021, gives the forestry sector a central role.[3] As a result of these efforts, Indonesia's rate of primary forest loss decreased for the fourth year in a row in 2020 and the country dropped out of the top three countries for primary forest loss for the first time in years.[4]

The Climate Investment Funds (CIF) support to the forestry sector in Indonesia is provided through the Forest Investment Program (FIP), a targeted initiative of the Strategic Climate Fund (SCF) within CIF. FIP was established in 2009 to finance efforts to address the underlying causes of deforestation and forest degradation, and to overcome barriers that have hindered past efforts to address the same issues.[5] The focus of this light-touch case study is three FIP projects in Indonesia to promote sustainable forest management (SFM):

- ***Community-Focused Investments to Address Deforestation and Forest Degradation*** (FIP-1): Led by the Asian Development Bank (ADB), this project aims to reduce emissions from deforestation and forest degradation in West Kalimantan, one of the top provinces contributing to greenhouse gas (GHG) emissions in Indonesia. The project is expected to be completed by June 2023. The project is funded at US$18.7 million, including a US$17 million CIF grant.[6]

- ***Promoting Sustainable Community-Based Natural Resource Management (CBNRM) and Institutional Development****:* Led by the World Bank, this project aims to strengthen institutional and local capacity for decentralized forest management and help improve forest-based livelihoods in targeted areas. It is expected to be completed by December 2022. The project is funded at US$22.42 million, including a US$17.35 million CIF grant.[7]

- ***Strengthening Rights and Economies of Adat and Local Communities*** (DGM-1)*:* Implemented by the World Bank, this project seeks to improve the capacity of participating Indigenous Peoples and local communities (IPLCs) to engage in tenure security processes and livelihood opportunities from sustainable management of forests and land. The project is expected to be completed by November 2022. It is funded entirely by CIF, at US$6.3 million.[8]

Based on a literature review and key informant interviews, this light-touch case study examines the development impacts (DIs) of these three FIP projects. The beneficiaries of the interventions are primarily customary law communities (or masyarakat hukum adat, MHA)[9] and IPLCs who inhabit most of the project sites.[10] It is estimated that the FIP-1 project reaches about 16,349 beneficiaries (including 6,901 women) in the 17 targeted villages, most of them farmers.[11] The Promoting Sustainable CBNRM and Institutional Development project is expected to benefit 95,000 people,[12] while the DGM-1 project will support nearly 8,000 people.[13]

Project stakeholders

At the national level, the key stakeholders of these projects include the Ministry of Environment and Forestry (MOEF) of Indonesia, comprising the Directorate General (DG) of Social Forestry and Partnerships (PSKL), DG of Sustainable Forest Management (PHL), and the DG of Climate Change Control (PPI) and Betung Kerihun and Danau Sentarum National Park (BBTNBKDS). The Agency of Fiscal Policy of the Ministry of Finance and the National Planning Board (BAPPENAS) also plays a key role in the FIP-1 project. Community-based organizations such as APDS (Asosiasi Periau Danau Sentarum) and Social Forestry groups in Kapuas Hulu and Sintang are primary stakeholders as well. In addition, the Samdhana Institute Indonesia is a key stakeholder in DGM-1.

Development impact pathways and case study focus

The potential impact pathways for these projects as identified by the evaluation team through input from stakeholders and literature review are presented in Figure 1. The projects' DIs are expected to be driven mainly by increased access to new markets, community engagement, and social inclusion.

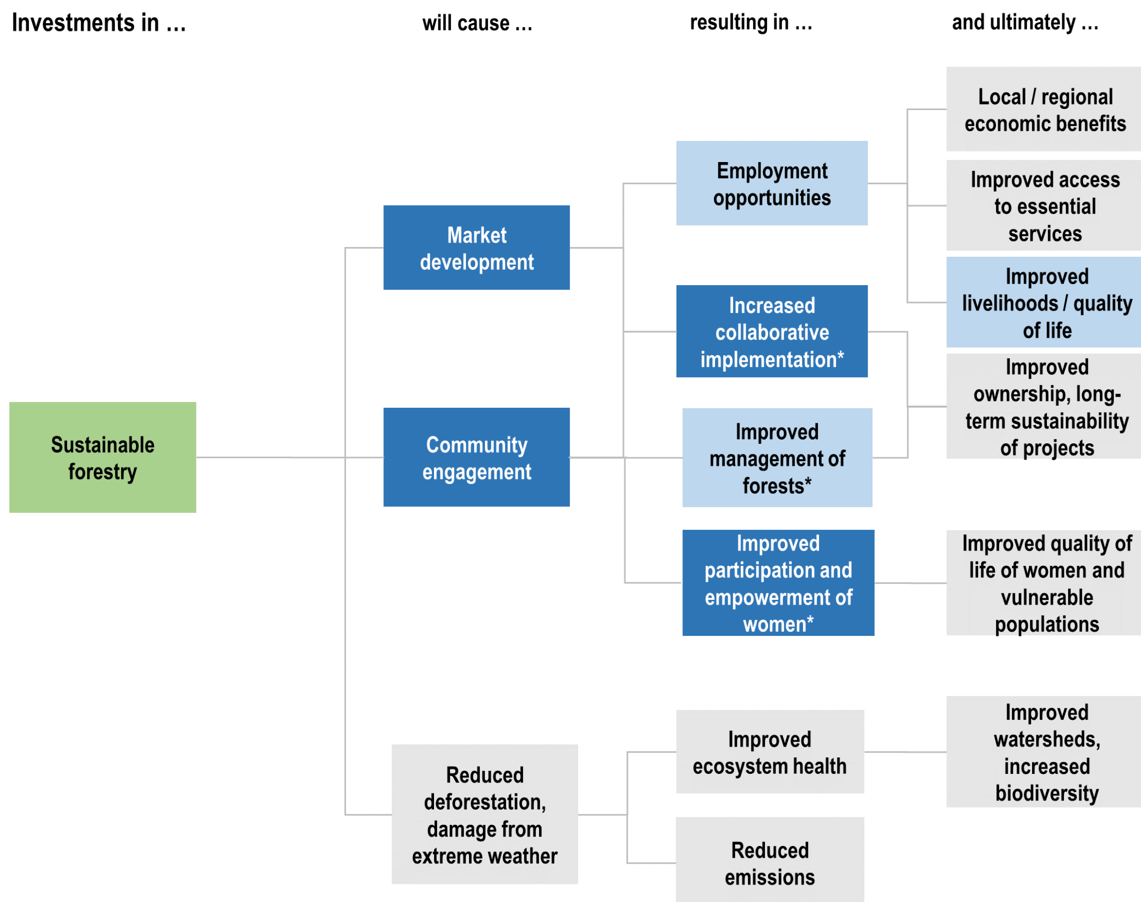
The **dark blue boxes** indicate the quantified DIs assessed in this case study: market development and community engagement resulting in increased collaborative implementation and improved participation and empowerment of women. The **light blue boxes** indicate the DIs qualitatively assessed in this case study (i.e., for which sufficient quantitative evidence is not yet available based on the project documentation): market development resulting in employment opportunities and improved livelihoods/quality of life, and community engagement resulting in improved management of forests.

The **gray boxes** indicate DIs that should follow from the investments when these are completed but are either too long-term to assess currently, and/or would require additional research and analysis to address:

- Local/regional economic benefits—would require additional research to understand if the promotion of new forest products and services through the projects had economic impacts at the regional level. It is too early to study this DI.
- Improved access to essential services (e.g., water, education)—would require additional research to determine how the promotion of new forest products and services, and the associated increased income, resulted in a higher quality of life and improved access to essential services (in particular, for women).
- Improved ownership, and long-term sustainability of projects—would require additional research to determine whether community engagement ultimately led to increased sustainability of projects in the long term. It is too early to study this DI.
- Reduced deforestation and damage from extreme weather resulting in improved ecosystem health and reduced emissions—would require additional research to understand if the scale of the project affected overall (long-term) forest resilience in Indonesia. It is too early to study this DI.

Of the broad list of DIs identified in our impact pathways, three were included in varying forms (metrics) in the available documentation across the projects included in this case study: increased collaborative implementation, improved participation of women, and improved management of forests. Examples of applicable metrics for these DIs in the project documents include "[*number of*] participants in consultation activities during project implementation," "[*number of*] community investment plans developed in participatory manner," "[*number of*] women in consultation activities during project implementation," "[*percentage of*] female beneficiaries who participated in projects' activities," and "[*number of*] government institutions provided with capacity building support to improve management of forest resources."[14]

Figure 7. Impact Pathways of Sustainable Forestry in Indonesia



** These DIs are included in the project documentation and have an associated metric.*

Development Impacts: Performance to Date

Market development resulting in employment opportunities

The projects have contributed to market development and thus to the promotion of new economic activities, in fields such as ecotourism, honey harvesting, and beekeeping, among others. To achieve this, FIP-1 supported the development of processing facilities for fish, coffee, lemongrass, rubber, and pepper, as well as nursery facilities, benefiting a total of 366 people from MHAs (213 men and 153 women).[15] Based on the project documentation, most were farmers and fishers, while others had no permanent jobs.[16]

Market development resulting in improved livelihoods and quality of life

As of December 2020, the Promoting Sustainable CBNRM and Institutional Development project had improved livelihoods by providing monetary and non-monetary benefits to around 71,000 people (the end target is 90,000), of which about 16,300 belonged to ethnic minorities (MHAs)[17] and about 32,300 were women. Monetary benefits were reflected in the communities' increased income. According to the stakeholders interviewed, the project had improved the beneficiaries' income by about 5–10 percent driven by activities such as honey production and packaging. Similarly, by 2021 FIP-1's programs had contributed to an increase in community income by 56 percent and 50 percent (relative to 2018) in Sintang and Kapuas Hulu Districts, respectively.[18] The projects have also increased access to essential services, mainly through the FIP-1 Village Infrastructure program,[19] which has funded the construction of two micro-hydro power plants, clean water facilities, and new road infrastructure in the two districts.[20] A monitoring report published in March 2022 indicates that the two micro-hydro power plants were already operating and supplying electricity to 190 households and four public facilities, including two hamlet offices, a church, and a community meeting room.[21]

Community engagement resulting in increased collaboration and improved forest management

Through the Promoting Sustainable CBNRM and Institutional Development project, 10 Forest Management Units (FMUs) (or Kesatuan Pengelolaan Hutan, KPH)[22] have been operationalized with the collaboration of the communities. The communities were actively involved in the development of sustainable long-term and annual forest management plans, and four had an MHA as community representative in the forest management process.[23] Moreover, by December 2021, five government institutions were provided with capacity building support to improve the management of forest resources. At the site level, this project has supported 95 forest farmer groups with community-based business development aimed at improving management of forests. The farmer groups have received capacity building on marketing strategy, business plan preparation, and access to finance/credit mechanisms.[24] This CBNRM training on forest management and new forest products and services was achieved through the roll-out of Knowledge Management and Information Systems (KMIs) at the national level, a Knowledge Resource Center at the subnational level, and capacity building and knowledge exchange activities that included e-learning and the utilization of smart classrooms for blended learning.[25,26] Of the KPH staff trained, 75 people are reported to be using skills from the training to effectively perform KPH management activities.

In addition, DGM-1 has supported vulnerable groups to obtain recognition of tenure rights. To date, a total of 63 subprojects have been implemented by IPLCs under DGM-1, of which 49 subprojects have focused on land tenure security and 14 have focused on livelihood activities. Thirty-five participating community groups have submitted evidence of tenure rights to the government in a number of districts, with varying levels of recognition.[27]

In general, community engagement within the CIF projects was favored by a close alignment with the Government's development plans and targets. For instance, the agrarian reform (Tanah Objek Reformasi Agraria, TORA) and Social Forestry program under Indonesia's Just Economy policy provided enabling conditions that favored decentralized land management. Stakeholders highlighted the role of these policies in increasing the land area that is accessible to communities, which was a key factor for all three CIF-SFM projects. Relationships between the government and the communities improved following the land reforms, which resulted in enhanced communication between actors. This closer interaction resulted in finding and introducing useful improvements from one CIF-SFM project to another in cooperation with governmental actors at the national and subnational levels.

Community engagement resulting in improved women's participation and empowerment

All three CIF projects examined had a specific gender component, included the development of Gender Action Plans, and engaged gender experts. Under FIP-1, women constitute at least 30 percent of the participants in all workshops, consultations, study visits, and implementation activities.[28] As a result, 197 women have been trained in topics including GIS, entrepreneurship, weaving techniques, non-timber forest products, gender empowerment, and a green school program.[29] According to key informant interviews, other economic activities with increased women participation are fish drying, preparation of fish products (such as sauces), and home gardening. The Promoting Sustainable CBNRM and Institutional Development project is expected to reach 28,500 women, or 30 percent of the total beneficiaries.[30] The DGM-1 subprojects have benefited nearly 2,230 women.[31]

The subprojects have strengthened the role of women in economic activities and contributed to closing the gender gap in the project areas. The project documentation confirms how gender roles in agriculture differ, with men typically carrying out activities such as tree felling and land clearing, burning, sowing, and transporting of goods.[32] As explained during the key informant interviews, the projects resulted in women adopting some of these traditionally male-dominated roles, particularly the load and transport of heavy equipment such as water pipes. The support provided to women has also included capacity building in aspects of agricultural business land tenure. As a result, the number of subprojects proposed and led by women within the forestry programs has been increasing, as mentioned during the interviews and confirmed by other evaluators.[33] Stakeholders also reported that a group of women developed and successfully submitted a subproject to DGM Indonesia, demonstrating the increasingly proactive involvement of women in such initiatives.

Besides contributing to economic empowerment, the interviews indicated that the CIF-SFM projects have enhanced women's conflict resolution role in their communities. During one key informant interview, it was mentioned that the project activities allowed women to play a more prominent (sometimes leading) role, and, as a result, women have shown increased confidence to intervene in negotiations and to resolve disputes between villages (e.g., border disputes). These results have inspired other vulnerable women subgroups that are frequently excluded, such as elderly and women heads of households.

In addition, the CIF-SFM projects have strengthened the conditions for sustaining women's participation in their communities. According to stakeholders, women in most of the project areas are typically marginalized, with little decision-making power and low representation compared with men. The projects included gender objectives in their design and have also conducted capacity-building activities to encourage local communities to include gender considerations when designing any type of intervention. Interviewees indicated that implementing partners including the Samdhana Institute have also increased their efforts to mainstream a gender perspective in their grantmaking.

Table 8. Summary of Quantified DI Benefits Assessed

DI	Included in original project documents?	Metric /KPI	Method of assessment
Market development	Yes	Number of beneficiaries of new activities, alternative sources of income	Estimation included in the project documents and interviews

Community engagement and social inclusion	Yes	Number of FMUs operationalized with the community/ Projects implemented by IPLC	Estimation included in the project documents and interviews
Improved quality of life and empowerment of women	Yes	Number of women benefited	Estimation included in the project documents and interviews

Other Implied DIs (Not Assessed)

Other potential impacts, including environmental and socioeconomic impacts, were mentioned briefly in project documents and stakeholder interviews. For instance, infrastructure improvements under FIP-1 are expected to have significant environmental and social impacts, including a reduction of 3.7 million tCO_{2e} of GHG emissions, improved watersheds, increased biodiversity, construction of access roads, and clean water facility development.[34] Forest resilience has been improved through community forest fire management trainings. In the same vein, the Promoting Sustainable CBNRM and Institutional Development project aims to achieve meaningful environmental benefits by improving forest management practices in 10 FMUs.

The interviews also identified potential negative impacts from the interventions. These include involuntary resettlement, as some inhabitants of the project sites had to free up land for roads, installation of water pipelines, or ecotourism facilities. Depending on the type of impact, different forms of compensation can be provided, such as cash compensation, benefit sharing, and allowances during the transition period.[35] The community that was affected is the project beneficiary, so residents were consulted to ensure they voluntarily joined the project.[36]

Restricted community access to forest areas was often perceived as negative, because the "free" use of land for traditional (typically unsustainable) uses was restricted under the projects. When community members faced access restrictions because of project activities, technical assistance for sustainable forest management and a daily monetary incentive during the transition period were provided.[37]

In general, for all three CIF-SFM projects examined, potential negative impacts were perceived as temporary. To avoid negative impacts, in all cases resettlement frameworks were prepared in consultation with the FMU and local governments.[38] Moreover, strong engagement with stakeholders as well as effective environmental monitoring at all stages of the project were necessary to ensure that potential negative impacts were avoided or addressed in a timely manner.[39]

Barriers to Sustainable Forest Management and Realizing DIs[40]

Two barriers to achieving DIs within CIF-SFM projects are:

a) ***Cultural barriers that limit female participation and lead to the underrepresentation of women***. Meeting some targets in the gender action plans has been challenging. Achieving the desired number of female participants has been difficult because the share of women working in governmental institutions is currently lower than the goals set by the projects. In addition, the interviews indicated that women are not always able to engage actively in the project activities due to their other responsibilities. For some women, participating in CIF-SFM projects would have posed an additional burden, which discouraged them from participating. To overcome this barrier, gender experts worked in the field to improve information dissemination and ultimately adjusted project activities to accommodate women's availability.

b) ***Changing framework for forest governance that disincentivizes and delays community engagement****.* According to some interviewees, recent government initiatives partly changed forest management roles in Indonesia, which required CIF-SFM project responsibilities to be reassigned, delaying some activities. Another barrier is related to the allocation of forest areas to Indigenous communities (i.e., the provision of legal access and acknowledgement of the right of the customary community to manage a forest area). To varying extents, the CIF-SFM projects intend to allocate forest areas to communities that can manage them sustainably, including Indigenous people. Some Indigenous communities are requesting the right to manage larger areas of forests; however, in some cases, the Indigenous population is very small and the assessment of their capacity to manage such large areas has proven challenging. Disagreement on these issues has delayed the allocation of forest areas to beneficiaries, according to some interviewees.

Future Opportunities for Realizing DIs through SFM in Indonesia

The three CIF-SFM projects in Indonesia have shown that there are still challenges for SFM both at the community and governmental levels. However, at the same time, the interventions have demonstrated strong community interest in SFM practices. Stakeholders agreed that the CIF-SFM projects were important catalysts that contributed to the government's recent efforts to pursue land reforms by, e.g., building knowledge on the functioning of FMUs and their interaction with local communities.

To track and assess the DIs more fully, the interviews indicated the need for metrics that better reflect the DIs on women. According to interviewees, impacts on women are not fully reflected in the project indicators and are generally underestimated. Women often perform multiple tasks in the field, making it difficult to establish an accurate baseline. Besides counting the number of women trained, projects could "tell the story" about how women became interested in SFM during the course of the project. Furthermore, the interviews suggested considering a broader scope of indicators, for instance, women who are indirect beneficiaries. For example, besides counting the number of male farmers trained, information about their wives (e.g., number, age) could also be recorded.

Representatives from the three CIF-SFM projects stated that knowledge sharing is essential. A common steering committee (or other mechanisms) for projects with complementary objectives was recommended for sharing best practices and ensuring effective implementation. Similarly, interviewees perceived that several project actors would benefit from increased dissemination of information and best practices through digital platforms. Interviewees also suggested that communication strategies should emphasize DIs that are "closer" to beneficiaries. For instance, reducing GHG emissions was often communicated as the FIP-1 project's main purpose, but focusing the narrative on other impacts (e.g., increased income) could have created greater interest in the local communities.

Effective coordination with the communities also helped to achieve DIs, in particular community engagement and social inclusion. The involvement of community-based organizations, according to stakeholders, enabled smooth communication and collective work with IPLC groups, building trust and facilitating their engagement throughout the projects. Similarly, proximity with the communities made it possible to recognize early during the COVID-19 pandemic how to support the beneficiaries to avoid or mitigate negative impacts.

Finally, stakeholders indicated that clear frameworks from the start of projects (such as Gender Action Plans) was key for enabling DIs.

Future Research

CIF should consider additional research to facilitate the analysis of additional DIs associated with SFM in Indonesia:

- Local regional and economic benefits, to determine how many new direct and indirect jobs were created through the implementation of SFM at different project sites;
- Impact of improved inclusion of communities and women on the planned forest protection outcomes, to determine how the increased participation of women affected the forest management dynamics within the communities;
- Improved livelihoods and quality of life, to understand the extent to which SFM contributed to increased (and diversified) income;
- Increased access to essential services, to determine how access to water, education and other essential services improved with the economic and employment opportunities created; an assessment of increased access to essential services by women would be particularly beneficial;
- Enhanced forest resilience (i.e., reduced damage from extreme weather and changing climate that causes flooding and landslides, among others) and its impact on quality of life (e.g., by reducing water quality and availability), to understand how communities benefit from improved fire management frameworks for forests.

Table 2. Interviewee List

Organization	Designation	Name
Indonesia Resident Mission Asian Development Bank	TTLs Community-Focused Investments to Address Deforestation and Forest Degradation (CFI-ADD+) project	Helena Lawira
		Karen L. Chua
PT Hatfield Indonesia (consulting firm)	National REDD+ Team Leader, Project Implementation Supporting Unit (PISU), FIP-1	Bambang Tri Sasongko Adi
Ministry of Environment and Forestry (MOEF), Indonesia	Project Management Unit, FIP-1	Sahala Simanjuntak
Ministry of Environment and Forestry (MOEF), Indonesia	Director of Business Development Assistance for Social Forestry and Tenurial Forest	Catur Endah Prasetyani
Ministry of Environment and Forestry (MOEF), Indonesia	Director of Production Forest Management Unit	Drasospolino
World Bank	Task team leaders, Promoting Sustainable Community-Based Natural Resource Management and Institutional Development project	Tini Gumartini
		Iwan Gunawan
		Efrian Muharrom

Endnotes

[1] Meijaard, E., Santika, T., Wilson, K. A., Budiharta, S., Kusworo, A., Law, E. A. & Struebig, M. J. (2021). Toward improved impact evaluation of community forest management in Indonesia. *Conservation Science and Practice*, *3*(1), e189.

[2] The Borgen Project (2021) The Decline of Deforestation In Indonesia. https://borgenproject.org/the-decline-of-deforestation-in-indonesia/

[3] (2021) Long-Term Strategy for Low Carbon and Climate Resilience 2050 (Indonesia LTS-LCCR 2050) https://unfccc.int/sites/default/files/resource/Indonesia_LTS-LCCR_2021.pdf

[4] WRI Indonesia (2021) Weisse, M and Goldman, E. Primary Rainforest Destruction Increased 12% from 2019 to 2020. https://wri-indonesia.org/en/blog/primary-rainforest-destruction-increased-12-2019-2020

[5] CIF Climate investment Funds- Sustainable Forests. https://www.climateinvestmentfunds.org/topics/sustainable-forests

[6] ADB Indonesia: Community-Focused Investments to Address Deforestation and Forest Degradation- Sovereign Project | 47084-002. See: https://www.adb.org/projects/47084-002/main

[7] See Indonesia - Promoting Sustainable Community-Based Natural Resource Management and Institutional Development Project- https://projects.worldbank.org/en/projects-operations/project-detail/P144269

[8] See Strengthening Rights and Economies of Adat and Local Communities. https://projects.worldbank.org/en/projects-operations/project-detail/P156473?lang=en

[9] Customary or Indigenous community is a distinct community that is characterized by; i) the existence of group of people who has a collective attachment to a certain customary legal order as a whole community of an alliance with a particular customary law, who recognizes and implements the tradition in their daily life; ii) the existence of certain customary lands, which are the environment of the customary community and the area where they take their daily needs; and iii) the existence of common law regarding the maintenance of order, dominance, and applicable customary land use adhered by the members of the community. PP No. 71/2012, Article 22. See (2021) Community-Focused Investments to Address Deforestation and Forest Degradation: Social Monitoring Report (January-June 2021). https://www.adb.org/projects/documents/ino-47084-002-smr-0 (Pag.x)

[10] In the case of the FIP-1 project, the majority of MHA consist of Dayak and Malay origin. Directorate General of Social Forestry and Partnership (2021) Community-Focused Investments to Address Deforestation and Forest Degradation: Sintang and Kapuas Hulu Districts of West Kalimantan Province Resettlement Plan. See: https://www.adb.org/projects/documents/ino-47084-002-rp, p. 11.

[11] See Factsheet. PROGRAM INVESTASI KEHUTANAN https://www.fip1-adb.com/factsheet/

[12] Gunawan, Iwan. Disclosable Version of the ISR - Promoting Sustainable CBNRM And Institutional Development - P144269 - Sequence No: 12 (English). Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/099625012172112888/Disclosable0Ve0269000Sequence0No012

[13] Gunawan, Iwan. Disclosable Version of the ISR - Strengthening Rights and Economies of Adat and Local Communities - P156473 - Sequence No: 10 (English). Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/099920012102124762/Disclosable0Ve0473000Sequence0No010

[14] Other objective indicators and associated metrics included in the CBNRM project documentation that are related to improved forest management include: "[*number of*] KPHs governed by sustainable long-term and annual forest management plans prepared or revised with community participation," "[*number of*] key regulations drafted through increased coordination and submitted for government review," "[*number of*] KPHs with forest boundaries that have been delineated in spatial plans and submitted to geospatial agency for being included in OneMap Policy," and "[*Yes/No*]Forest Information System Operational." Furthermore, the FIP-1 project includes a target on the [*number of*] hectares dedicated to agroforestry activities.

[15] ADB (2021). Community-Focused Investments to Address Deforestation and Forest Degradation: Social Monitoring Report (January-June 2021). See: https://www.adb.org/projects/documents/ino-47084-002-smr-0

[16] Directorate General of Social Forestry and Partnership (2021) Community-Focused Investments to Address Deforestation and Forest Degradation: Sintang and Kapuas Hulu Districts of West Kalimantan Province Resettlement Plan. See: https://www.adb.org/projects/documents/ino-47084-002-rp, page 13.

[17] Gunawan, Iwan. Disclosable Version of the ISR - Promoting Sustainable CBNRM And Institutional Development - P144269 - Sequence No: 12 (English).

[18] The baseline income in Kapuas Hulu was IDR 26 million per HH per year and has become IDR 39 million per HH per year. While in Sintang, the baseline in 2018 was measured at IDR 19 million and has become IDR 29.8 million per HH per year. Monitoring on community income was conducted in May-June 2021. This has exceeded the target of 20% of community income increase at the end of the project. (2021) Community-Focused Investments to Address Deforestation and Forest Degradation: Social Monitoring Report (January-June 2021). See: https://www.adb.org/projects/documents/ino-47084-002-smr-0. Tables 19 and 20

[19] ADB (2021). Community-Focused Investments to Address Deforestation and Forest Degradation: Social Monitoring Report (January-June 2021). See: https://www.adb.org/projects/documents/ino-47084-002-smr-0. Pag 14

[20] In total, the FIP-1 project aims to construct 34 units of clear water, fund 17 packages of road construction, two green school buildings and two packages of micro hydropower plants. (2021) Community-Focused Investments to Address Deforestation and Forest Degradation: Social Monitoring Report (January-June 2021). See: https://www.adb.org/projects/documents/ino-47084-002-smr-0. Table 1

[21] ADB (2022). Indonesia: Community-Focused Investments to Address Deforestation and Forest Degradation. Environmental Monitoring Report. https://www.adb.org/projects/documents/ino-47084-002-emr-6 Pag.1

[22] Forest Management Units (FMUs) were established by the Government of Indonesia as permanent management entities aiming to improve forest governance, planning, forest resources (co-)management, monitoring, and stakeholder engagement. An FMU is i) a public service provider under the responsibility of central, regional and district authorities, ii) an operational unit of manageable and controllable size predominantly covered by forests, iii) a legally established permanent entity with clearly demarcated forest boundaries. An FMU has clear economic, social, and ecological management objectives stipulated by long-term management plans (co-developed with the communities), annual work and business plans. In particular, FMUs have high potential to promote forest and non-forest product commodities and innovative frameworks for involving communities and the private sector (e.g., in setting up sustainable value chains), which provides additional local jobs and income.

For more information on FMUs, see FORCLIME (2012). Frequently asked questions (FAQ)- Forest Management Unit (FMU). Available at: https://www.forclime.org/documents/Brochure/English/FAQ%20FMU_English.pdf

[23] See Indonesia - Promoting Sustainable Community-Based Natural Resource Management and Institutional Development Project- https://projects.worldbank.org/en/projects-operations/project-detail/P144269

[24] The project documentation states that farmer groups received support for accessing finance, but it does not provide additional information on the extent to which financing was provided/achieved.

Gunawan, Iwan. Disclosable Restructuring Paper – Promoting Sustainable CBNRM and Institutional Development - P144269 (English). Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/172261624984987978/Disclosable-Restructuring-Paper-PROMOTING-SUSTAINABLE-CBNRM-AND-INSTITUTIONAL-DEVELOPMENT-P144269

[25] Based on the project documentation, the KMIS's purpose is to contribute to data compilation, analysis, visualization, storage, and dissemination and creation of knowledge products. It includes data at the national, subnational, and FMU level such as forest cover, forest inventory data, laws, socioeconomic parameters, and carbon emissions. Specifically, the activities under the project sought to make available electronically existing information on socioeconomic, institutional, biophysical, and environmental parameters including data that is only available in hardcopies of relevant reports and maps. The tools can be used by national and subnational government and nongovernment stakeholders, and local communities, to improve knowledge on sustainable forest management.

[26] In this context, a smart classroom is a room supported with digital audio and visual technologies designed for interactive and modern learning to carry out online workshops and webinars on SFM.

[27] Gunawan, Iwan. Disclosable Version of the ISR - Strengthening Rights and Economies of Adat and Local Communities - P156473 - Sequence No: 10 (English).

[28] Gender Action Plan (GAP) Community-Focused Investments to Address Deforestation and Forest Degradation Project: Gender Action Plan. https://www.adb.org/projects/documents/ino-community-focused-investments-address-deforestation-gap

[29] ADB Indonesia: Community-Focused Investments to Address Deforestation and Forest Degradation- Sovereign Project | 47084-002. See: https://www.adb.org/projects/47084-002/main

[30] Gunawan, Iwan. Disclosable Version of the ISR - Promoting Sustainable CBNRM And Institutional Development - P144269 - Sequence No: 12 (English).

[31] Gunawan, Iwan. Disclosable Version of the ISR - Strengthening Rights and Economies of Adat and Local Communities - P156473 - Sequence No: 10 (English).

[32] Directorate General of Social Forestry and Partnership (2021) Community-Focused Investments to Address Deforestation and Forest Degradation: Sintang and Kapuas Hulu Districts of West Kalimantan Province Resettlement Plan. See: https://www.adb.org/projects/documents/ino-47084-002-rp Pag. 16

[33] Dourhwaite, B., et al (2019). A Learning Review of the Dedicated Grant Mechanism (DGM) for Indigenous Peoples and Local Communities in the Forest Investment Program (FIP) of the Climate Investment Funds (CIF). https://www.climateinvestmentfunds.org/knowledge-documents/learning-review-dedicated-grant-mechanism-dgm-indigenous-peoples-and-local

[34] ADB Indonesia: Community-Focused Investments to Address Deforestation and Forest Degradation- Sovereign Project | 47084-002. See: https://www.adb.org/projects/47084-002/main

[35] In contrast, for loss of land due to water pipeline network construction which crosses the land, no compensation was provided. In the case of temporary loss of income due to attending project events such as training, affected persons were entitled to apply for cash compensation. See Directorate General of Social Forestry and Partnership (2021) Community-Focused Investments to Address Deforestation and Forest Degradation: Sintang and Kapuas Hulu Districts of West Kalimantan Province Resettlement Plan.

[36] The Indigenous Peoples Planning Framework was prepared to safeguard MHA rights in accordance with the Indonesian national and provincial laws or regulations. For example, it establishes that meaningful consultation is built upon the free, prior and informed consent (FPIC) principles which addresses the right of community to be informed, consulted and to exercise their right to

accept or refuse initiatives offered to them by outsiders. See https://www.adb.org/projects/documents/ino-community-focused-investments-deforestation-and-forest-degradation-jun-2016-ippf

[37] Ibid.

[38] See, for instance: Directorate General of Social Forestry and Partnership (2021) Community-Focused Investments to Address Deforestation and Forest Degradation: Sintang and Kapuas Hulu Districts of West Kalimantan Province Resettlement Plan. See: https://www.adb.org/projects/documents/ino-47084-002-rp

[39] ADB Indonesia: Community-Focused Investments to Address Deforestation and Forest Degradation- Sovereign Project | 47084-002. See: https://www.adb.org/projects/47084-002/main

[40] Insights about enabling the achievement of DIs are included in the section on Future Opportunities for Realizing DIs through SFM in Indonesia.

8. Kenya Light-Touch Case Study: Development Impacts of Off-Grid Electrification

Project Details	Funding
Name: Kenya Electricity Modernization Project **Country:** Kenya **CIF Program Area:** Scaling-up Renewable Energy Program in Low-Income Countries (SREP) **Bank approval:** March 2015 **Effective since:** June 2015 **Expected closing:** December 2022 **MDB:** World Bank	**Total Value:** $462 million **CIF:** $7.5 million grant **Co-financing:** $454 million **MDB**: $250 million loan, $200 million guarantee **Kenya Power and Lighting Co.:** $3.5 million **Instrument type:** Grant, loan, guarantee **Sector:** Public *Note: Totals are based on the December 2022 Implementation Status & Results Report.*

Key Highlights

- The Kenya Electricity Modernization Project (KEMP) is a US$462 million project that aims to increase access to electricity, improve service reliability, and strengthen the financial position of the national electric utility company.
- This case study focuses on the C2 subcomponent of the KEMP project, off-grid electrification, with a total CIF investment of US$7.5 million.
- The C2 subcomponent has not yet been fully implemented, but important progress has been made. At the time of this writing, implementation was expected by December 2022.

Topline Findings on Development Impacts

- **Access to essential services:** Off-grid electrification is expected to bring electricity to about 13,500 people in remote areas of Kenya, significantly improving access to essential services.
- **Gender-inclusive benefits:** Improved access to electricity is expected to specifically benefit women, who are traditionally responsible for collecting firewood for household energy in rural Kenya.
- **Employment:** The C2 KEMP subcomponent may translate into 88 direct short-term jobs (about one year) and about 10 annual direct jobs for 25 years. We estimate that the off-grid subcomponent may translate into 232 indirect short-term jobs.
- This program marks the first time in Kenya that an agreement was reached where the private sector is responsible for both operations and maintenance (O&M), and engineering, procurement and construction (EPC) of an off-grid electricity generation contract in the public sector. This agreement should significantly reduce the costs for the national electric utility KLPC and foster innovation, while maintaining the current national electricity tariff for beneficiaries.

Climate Investment Context and Overview

Kenya has set out to achieve universal access to electricity by 2022 and has worked intensively to achieve this. As a result, in the past decade, it has made annualized gains of more than 3 percentage points per year, advancing from 19.2 percent in 2010 to 71.4 percent in 2020.[1] However, given the significant gap that remains, the target has yet to be reached. Key challenges include the high cost of on-grid electricity, which is driven by high connection charges, and poor reliability.[2]

Another major obstacle is the geographical distribution of Kenya's population. While 94 percent of urban Kenyans have access to electricity, only 62.7 percent of rural residents do.[3] A third of the population is spread across the country's vast arid and semi-arid North and Northeast—areas that are sparsely populated and thus expensive to connect to the national grid.[4] Off-grid solutions are recognized as the most cost-effective option for achieving rural electrification in such areas of the country.

CIF joined implementing partners the African Development Bank (AfDB) and the World Bank to improve electricity access in rural areas. In total, CIF has supported four projects in Kenya through the Scaling-Up Renewable Energy Program in Low-Income Countries (SREP) and the Clean Technology Fund (CTF).[5]

The Kenya Electricity Modernization Project (KEMP) is one of those four projects.[6] It aims to increase access to electricity, improve service reliability, and strengthen the national electric utility company's financial position. The total investment in KEMP is US$462 million.[7] The project includes four components:

A. Improvement in service delivery and reliability (US$47 million)

B. Revenue protection program (US$32.48 million)

C. Electrification program, which targets households and businesses for connectivity through peri-urban (grid-connected) (C1) and off-grid (C2) electrification (US$175.02 million)

D. Technical assistance and capacity building (US$7.5 million)

CIF funding for the KEMP project has been limited to subcomponent C2, off-grid electrification. In addition, the project includes an International Development Association (IDA) guarantee for US$200 million in support of refinancing short-term commercial debt obligations of the Kenya Power and Lighting Company (KPLC). The project documentation also notes that $500 million in private capital has been mobilized.[8]

Project objectives related to CIF financing

This light-touch case study examines KEMP's development impacts (DIs), emphasizing the CIF-funded off-grid electrification subcomponent (C2). The beneficiaries are isolated villages for which electrification is not economically feasible through grid extension (e.g., islands in Lake Victoria). This light-touch case study is based on interviews and a literature review.

Project stakeholders

The key project stakeholders include KPLC, the Ministry of Energy and Petroleum (MoEP), and the Rural Electrification and Renewable Energy Corporation (REREC) (previously known as Rural Electrification Authority). REREC is responsible for the implementation of subcomponent (C2).

Development impact pathways and case study focus

As shown in Figure 1, this project is expected to result in DIs originating from increased access to reliable and clean electricity. In particular, the off-grid subcomponent targets villages that are challenging to reach and are unlikely to be electrified soon through the government's grid-connection plans. Through increased electricity access, benefiting households will have access to social services including health and education and will have more opportunities to improve their quality of life.[9] The project implementation status and results (ISR) reports track the number of people provided with access to electricity under the project by off-grid/grid household connections, residential connections made, the number of mini-grids constructed with public-private participation, and the associated annual electricity output, among other metrics.[10]

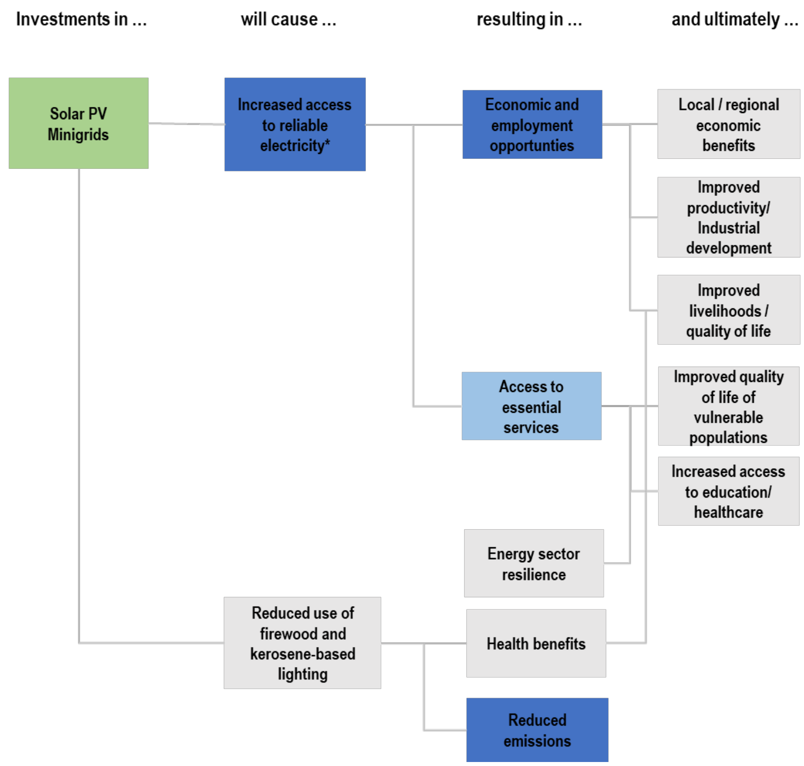
This light-touch case study focuses on the DIs shown in Figure 1. The evaluation team identified these DIs as the most relevant based on input provided by stakeholders: The **dark blue** boxes indicate the DIs quantitatively addressed in this case study: a) improved electricity access/increased reliability resulting in b) economic and employment opportunities and reduced use of firewood and kerosene-based lighting, resulting in c) reduced emissions. The **light blue** boxes indicate the DIs qualitatively addressed in this case study: d) access to essential services.

The **gray** boxes indicate DIs that should follow[11] from the investments after project completion, but are either too long-term and/or would require additional research and analysis to assess. Specifically:

- Local/regional economic benefits, improved productivity and industrial development, and improved livelihoods and quality of life (including for vulnerable populations) are expected to follow from economic and employment opportunities. Each of these impacts would require follow-up surveys to assess in the years after the mini-grids become active.
- Increased access to education and healthcare—would require additional research once the project is completed to determine how access to, e.g., schools and hospitals has improved with the installation of the mini-grids.
- Health benefits (and subsequent quality of life impacts) resulting from reduced use of fuelwood—would require extensive analysis to determine health impacts from improved air quality.
- Energy sector resilience—the deployment of the mini-grids ensures a degree of autonomy from the national grid and thus enhances the resilience of the energy sector and the affected communities to the impacts of climate change (e.g., in the event of a climate-related natural disaster affecting the national grid).

According to the November 2021 ISR report,[12] the off-grid subcomponent of the KEMP had not yet been implemented. However, according to key informant interviews, important progress has been made, including the completion of contract agreements as well as procurement and manufacturing of the necessary equipment. The latest ISR, issued in December 2022, notes that two out of seven planned mini-grids were expected to be completed by December 30, 2022, while the other five would be completed by the extended project closing date of June 30, 2023.[13] About 15,000 beneficiaries will now be connected, up from the original target of 13,500. The grid-connected subcomponent (C1), meanwhile, is operational and has already exceeded some of its targets.[14]

Figure 9. Impact Pathways of Off-Grid Electrification in Kenya



* These DIs are included in the project documentation and have an associated metric

Development Impacts: Quantified Results to Date

Increased access to reliable electricity

Electricity access is expected to improve significantly. As noted, the installation of the mini-grids was originally expected to bring electricity to about 13,500 people in remote parts of Kenya that previously had little or no electricity access, and now may reach 15,000.[15]

Economic and employment opportunities

Improved electricity access and reliability are expected to result in direct economic and employment opportunities.[16] The project has already created direct, civil work employment opportunities where the mini-grids are being installed, and it is expected to create future employment in construction and installation and during the operations and maintenance (O&M) phase. Once the grid becomes operational, direct employment opportunities in technical services (e.g., electrical, mechanical engineers) and supporting services (e.g., security personnel) are also anticipated.

An impact assessment of the construction of the mini-grids on one of the target islands (Mageta) predicted that it would create employment opportunities, particularly for casual workers from the local community including masons, carpenters, electricians, and engineers.[17] However, interviewees indicated that the use of new technologies for the mini-grids (e.g., automation and remote monitoring) may reduce some of the anticipated direct job creation at the local level. Based on a recent study that estimated mini-grid related employment opportunities in Kenya, the off-grid subcomponent of the KEMP may translate into 88 direct short-term jobs (lasting about one year) related to capital expenditures (excluding manufacturing and supply, as this is mainly taking place abroad) and about 10 annual direct jobs related to O&M for a period of 25 years, or the lifetime of the installed mini-grids.[18]

Similar projects have shown that increased access to electricity in Kenya also translated into increased indirect economic and employment opportunities.[19] Access to electricity enables the use of electric equipment and tools by enterprises, resulting in significant productivity improvements (100–200 percent depending on the task) and corresponding growth in income levels of small and micro-enterprises, such as carpentry and tailoring shops (on the order of 20–70 percent, depending on the product made).[20] In terms of indirect employment creation, we estimate that the off-grid subcomponent of the KEMP may translate into 232 indirect short-term jobs.[21] Key project stakeholders confirmed the indirect impact on economic opportunities, pointing out as an example the positive effect that the mini-grids will have on the fishing industry. According to interviewees, increased access to reliable electricity will provide more options for storage (refrigeration) of fishing products and will open opportunities for trade and/or restaurants, ultimately benefiting local economies.

Reduced emissions

By reducing the use of firewood and kerosene-based lighting, the project is also expected to reduce greenhouse gas (GHG) emissions. A recent study by the Technical University of Denmark concluded that mini-grids investments in Kenya contribute to 16 Sustainable Development Goals (SDGs), including the climate goal.[22] The researchers estimated that the introduction of 146 solar PV mini-grids in Kenya with a total capacity of 6.5 MWp would reduce annual GHG emissions by 4,900 tons CO_2e. Scaled down to the KEMP mini-grids, these results roughly translate into a reduction of about 1,050 tons CO_2e per year.[23] This reduction corresponds directly to SGDs 7 (access to affordable, reliable, sustainable and modern energy for all), 9 (resilient infrastructure), and 13 (climate action).

Table 10. Summary of Quantified DI Benefits Assessed

DI	Included in original project documents?	Metric /KPI	Method of assessment
Access to electricity	Yes	Number of people with access to (reliable) electricity for the first time	Estimation included in project documentation
Direct job creation	No	Number of direct jobs	Quantitative analysis based on external literature
Indirect job creation	No	Number of indirect jobs	Quantitative analysis based on external literature
Reduced emissions	No	GHG emissions reduction	Quantitative analysis based on external literature

Other Implied DI Impacts (Qualitatively Assessed)

Access to essential services

More reliable electricity at the household level, and for other connected buildings such as schools, businesses, and clinics, can lead to improved access to essential services. For example, accessibility and quality of education will likely[24] improve through better lighting systems, the possibility to use information and communications technology (ICT) tools for learning, and laboratory equipment. Electrification is also expected to result in improve the quality and accessibility of healthcare—e.g., health clinics open longer hours, improved childbirth outcomes, and the preservation of vaccines. Moreover, it has the potential to expand and/or improve public services that provide a range of social benefits, including the social inclusion of isolated villages through improved communications and information access; and improvements to education and awareness on a variety of issues, including HIV/AIDS.[25]

Other Implied DI Benefits (Not Assessed)

Project documents and stakeholder interviews identified other potential, indirect impacts from the installation of mini-grids:

Local and regional economic benefits, and improved livelihoods and quality of life for vulnerable populations: Local and regional economic benefits and poverty reduction are expected to follow from the project's economic and employment impacts. In line with recent studies in Kenya, stakeholders reported that improved access to electricity will especially benefit women, who are traditionally responsible for collecting firewood for household energy in rural Kenya and thus often miss educational opportunities.[26] The project is also expected to indirectly improve the inclusion of women and youth in consultations with communities impacted by the installation of mini-grids, thus promoting gender and youth representation.[27]

Access to essential services: Increased access to education and healthcare is expected to result from increased reliable electricity supply, e.g., through lighting and appliance use in schools, and through use of refrigeration to extend the range of medicines available in healthcare settings.

Health benefits: Health benefits from improved indoor air quality are expected to result from decreased use of fuelwood, charcoal, and kerosene-based lighting in poorly ventilated homes as people use electric options instead (provided by the mini-grids). This could be highly beneficial to all who now breathe the polluted air, particularly women and children, who spend more time at home.[28]

Energy sector resilience: The installation of the mini-grids could provide more reliable electricity service to remote communities than they might otherwise be able to obtain, providing local resilience through the use of storage technologies and contracts for maintenance. Nationally, the deployment of mini-grids can support the country's electrification efforts. The use of the novel O&M contracting arrangements pioneered in this project can help reduce the maintenance burden on KPLC, improving their financial position and contributing to increased energy sector resilience. This can also potentially free up funding that otherwise would have been spent on O&M to be spent on mini-grids in other areas.

Some concerns have been raised, however, about potential negative impacts related to transforming land into installation sites for the mini-grids. The project documentation reported that the repurposing of land may result in involuntary resettlement. Precautionary measures have been taken to minimize the impacts on physical and cultural resources (e.g., on the Mageta island), ecologically important areas, and vegetation and wildlife, but damages may still occur.[29] The project documentation notes that these impacts are expected to be temporary (e.g., occurring during the construction phase) and minimal.

Enabling Conditions and Barriers to Achieving Development Impacts

Close cooperation with the government (MoEP and local governments) has been key to the program's progress. In particular, county governments provided essential support for land acquisition, including the granting of land ownership and tenure required for the implementation of project activities. This support has eased a process that is typically arduous and lengthy. Active stakeholder engagement with MoEP has helped align the project with political targets and garnered support for the project, including from REREC.

Barriers to off-grid electrification and realizing DIs

According to stakeholders, one of the key barriers that hindered the realization of DIs through the development of the KEMP project was the **lack of familiarity with novel business models that increase private sector participation**. According to stakeholders, the supply and installation contract for the KEMP mini-grids was considerably delayed by challenges in reaching an agreement on an O&M contract that ensures affordable electricity for consumers. The Kenyan tariff system, which ensures the provision of a universal tariff for electricity for consumers, creates an O&M funding gap that the contractor must fill. Traditionally, O&M for mini-grids in Kenya has been the responsibility of the national utility, KPLC; however, for the KEMP Electrification Program, the private sector was involved in this task to increase private sector engagement in renewable energy financing. This business model was new in Kenya and the process was unfamiliar to key stakeholders, including the monitoring and regulatory agencies. As a result, the project has needed more time and guidance from CIF than anticipated, including the engagement of transactional advisors to develop a suitable business model.

Additional barriers to off-grid electrification and realizing DIs in Kenya have been reported in other studies. In relation to economic and employment opportunities, a recent analysis showed that renewable energy project developers face difficulties recruiting and retaining talent in Kenya (in particular, managerial positions); this is an obstacle to the rapid expansion of the country's off-grid electrification.[30] Other barriers that have prevented the use of renewable electricity for lighting in Kenya include concerns that it is risky to use and misconceptions about the cost.[31] Recent research that examined the socioeconomic determinants of the Kenyan household's lighting fuel choice identified low income and education as factors that impede the adoption of clean lighting solutions.[32]

Regarding access to essential services and quality of life, some of the most commonly cited barriers to realizing these benefits for women are broader sociocultural challenges involving gender stereotypes, recruitment biases, discriminatory business cultures, and perceptions of gender roles.[33] There is also a lack of data and market information about female customers, their needs, and the characteristics of their energy demand, and women have unequal access to assets and land ownership, which directly affects their ability to access energy products.[34] The literature also reports that mistrust and corruption may hinder the achievement of DIs in Kenya, particularly in areas with vulnerable populations who struggle to navigate bureaucratic connection processes, leading to resentment and avoidance of electrification solutions.[35]

Future Opportunities for Realizing DIs through Off-Grid Electrification

Previous studies have found that mini-grid deployment may represent the most cost-effective option for electrification and long-term electricity provision to unelectrified households in rural Kenya.[36] As discussed above, the KEMP program has shown that close cooperation with the government (MoEP and local governments) is key to advancing DIs from mini-grid projects. This cooperation is crucial to implementing off-grid projects in remote areas and thus increasing electricity access for a large part of the marginalized population in the country's rural areas.

Furthermore, the KEMP program has shown that diversifying the sources of capital for energy projects is necessary to expand Kenya's off-grid electrification and thus achieve the associated DIs. Despite the implementation delay caused by the O&M contract for the mini-grids, stakeholders perceive the agreement that was reached as one of the project's main achievements that can foster off-grid development in Kenya. It is the first time that such an agreement, with the private sector responsible for both O&M and EPC, has been signed in Kenya. Compared with the traditional approach, the involvement of private contractors is expected to significantly reduce the costs for KPLC and foster the use of innovative and more effective technologies (e.g., remote monitoring).

According to stakeholders, the involvement of private actors through the KEMP O&M contract could be seen as a good practice example applicable to other sectors and could contribute to expanding access to essential services in remote areas in Kenya. Stakeholders observed that the successful implementation of the KEMP project would demonstrate a new, lower-cost approach to O&M for off-grid systems, which could free up funding for more off-grid systems overall. This approach could be replicated by other utilities, such as waste or water management utilities. CIF (and other funders) could consider supporting the integration of mechanisms to expand private sector participation in future updates of national plans.

Finally, to sustain the DIs of off-grid electrification projects, future CIF and other interventions in Kenya should aim to ensure that the workforce is trained to benefit from the jobs created. It has been estimated that by 2022–2023, the decentralized renewable energy sector in Kenya will provide more than 17,000 direct formal jobs, and about 29 percent of these jobs will support the growing mini-grid sector.[37] The growth of the mini-grid sector may also create more demand for management, project development, and installation talent.

Future Research

Potential areas for future research include:

- Impacts of mini-grids on the use of firewood and kerosene-based lighting, and consequent reductions in emissions and improvements in indoor air quality.
- Impacts of mini-grids on access to education and healthcare, including, e.g., benefits of increased use of ICT tools for learning and laboratory equipment in healthcare facilities.
- Impacts of mini-grids on improving quality of life of vulnerable populations, including children and women.

Table 3. Interviewee List

Organization	Designation	Name
World Bank	KEMP Task Team Leader	Zubair K. M. Sadeque
World Bank	KEMP Task Team Leader	Laurencia Karimi Njagi
REREC	REREC Business Development Manager	Edward Gakunju

Endnotes

[1] IEA, IRENA, UNSD, World Bank, and WHO (2022). Tracking SDG 7: The Energy Progress Report 2021. Joint report by the International Energy Agency, the International Renewable Energy Agency, United Nations Statistics Division, World Bank, and World Health Organization. Washington, DC: World Bank. https://trackingsdg7.esmap.org .
See also the latest statistics for Kenya at https://trackingsdg7.esmap.org/country/kenya.

[2] CCG (2021). Rapid Electrification in Kenya: Progress, challenges, and practical geospatial solutions. Available at: https://climatecompatiblegrowth.com/wp-content/uploads/2021/08/5E-COP26-Policy-Brief.pdf

[3] See Tracking SDG 7 statistics for Kenya: https://trackingsdg7.esmap.org/country/kenya.

[4] NewClimate (2019). The role of renewable energy mini-grids in Kenya's electricity sector. https://newclimate.org/2019/11/12/the-role-of-renewable-energy-mini-grids-in-kenyas-electricity-sector/

[5] Besides the KEMP, CIF also supports the Menengai Geothermal Development Project, the Kopere Solar Park, and the Concessional Finance Program for Geothermal Generation, the former of which is complete, the latter two awaiting MDB approval.

[6] World Bank documents for this project are available at: https://projects.worldbank.org/en/projects-operations/project-detail/P120014.

[7] Based on Njagi, Laurencia Karimi. Disclosable Restructuring Paper - KE Electricity Modernization Project - P120014 (English). Washington, D.C.: World Bank Group.http://documents.worldbank.org/curated/en/229281631273743068/Disclosable-Restructuring-Paper-KE-Electricity-Modernization-Project-P120014 and Disclosable Version of the ISR - KE Electricity Modernization Project - P120014 - Sequence No: 14 (English). Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/099905312172110566/Disclosable0Ve0014000Sequence0No014

[8] See ISR dated Dec. 22, 2022: https://documents1.worldbank.org/curated/en/099230012222229088/pdf/P120014037a58e0dc0b7270998c27e777ec.pdf.

[9] Multiple studies have analyzed the impact of increased access to electricity on improved quality of life. For instance, IASS (2021) synthesizes the evidence related to the potential benefits of accelerating RE development in Kenya, including economic opportunities, sustained access and effective use of affordable, reliable, sustainable energy services, gender inclusivity and equity, among others. The UN (2021) analyzes the impact of energy access on poverty reduction, economic growth, human development, and environmental protection. See IASS (2021) *Status and trends of energy development and climate action in Kenya*, available at: https://www.cobenefits.info/wp-content/uploads/2021/07/COBENEFITS-Impulse_Energy_Climate-Action_Kenya.pdf; and UN (2021) Theme Report on Energy Access: *Towards the achievement of SDG7 and net-zero emissions*, available at: https://www.un.org/sites/un2.un.org/files/2021-twg_1-061921.pdf.

[10] KE Electricity Modernization Project - Project Development Objective Indicators. Latest from Nov 2021. Available at: https://projects.worldbank.org/en/projects-operations/project-detail/P120014

[11] Based on literature review Dal Maso, M et. al (2020). *Sustainable development impacts of nationally determined contributions: assessing the case of mini-grids in Kenya.* Climate Policy, 20(7), 815-831; NewClimate (2019) *The role of renewable energy mini-grids in Kenya's electricity sector.* https://newclimate.org/2019/11/12/the-role-of-renewable-energy-mini-grids-in-kenyas-electricity-sector/

[12] See WB KE Electricity Modernization Project: https://projects.worldbank.org/en/projects-operations/project-detail/P120014

[13] See ISR dated Dec. 22, 2022: https://documents1.worldbank.org/curated/en/099230012222229088/pdf/P120014037a58e0dc0b7270998c27e777ec.pdf.

[14] For instance, over 9,000 km of distribution lines had been constructed (7,000 km was the target) and 143,000 residential connections had been made (from 120,000 originally envisaged). See https://projects.worldbank.org/en/projects-operations/project-detail/P120014

[15] See indicator People provided with access to electricity under the project by household connections – Off- grid/mini-grid only (renewable sources) (Cumulative) under Project Development Objective Indicators KE Electricity Modernization Project - Project Development Objective Indicators. Available at: https://projects.worldbank.org/en/projects-operations/project-detail/P120014. Alternative estimates of 7,500 households have also been provided, given average household sizes of around 5 people, then this would mean the project reaches more people.

[16] In line with a large body of literature that confirms this, such as NewClimate (2019) *The role of renewable energy mini-grids in Kenya's electricity sector.* https://newclimate.org/2019/11/12/the-role-of-renewable-energy-mini-grids-in-kenyas-electricity-sector/; IASS (2021) *Status and trends of energy development and climate action in Kenya.* Available at: https://www.cobenefits.info/wp-content/uploads/2021/07/COBENEFITS-Impulse_Energy_Climate-Action_Kenya.pdf., and UN

(2021) Theme Report on Energy Access: *Towards the achievement of SDG7 and net-zero emissions.* Available at: https://www.un.org/sites/un2.un.org/files/2021-twg_1-061921.pdf.

[17] Nyamori, S. (2019) Environmental and Social Impact Assessment (Esia) Project Report for The Proposed 60kw Mini Grid in Mageta Island, Mitundu Sub-Location, Mageta Location, Bondo Sub-County Siaya County. Available at: https://www.rerec.co.ke/images/projects/MagetaESIA/Mageta-ESIA.pdf.

NewClimate (2019) The role of renewable energy minigrids in Kenya's electricity sector. https://newclimate.org/2019/11/12/the-role-of-renewable-energy-mini-grids-in-kenyas-electricity-sector/

[18] Calculated assuming that the six-mini grids will deliver annually 2,780 MWh which corresponds to approximately 1.4 MW of installed capacity based on an annual average electricity output of a 130W solar panel without reflectors in Kenya (690 Wh/day) (See Barman, J. (2011) Appendix 1- Design and feasibility study of PV systems in Kenya https://publications.lib.chalmers.se/records/fulltext/155055.pdf). The values presented by NewClimate (2019) were used to calculate the direct employment impacts. According to the report, a 1 MW mini-grid system in Kenya creates approximately 63 direct short-term jobs (1 year) for professional services (21) and construction (42) and 7 direct annual jobs related to ongoing operational expenditures for a period of approximately 25 years or the lifetime of the installed mini grids.

[19] IASS (2021) *Status and trends of energy development and climate action in Kenya.* Available at: https://www.cobenefits.info/wp-content/uploads/2021/07/COBENEFITS-Impulse_Energy_Climate-Action_Kenya.pdf.

[20] Kirubi, C., Jacobson, A., Kammen, D. M., & Mills, A. (2009). Community-based electric micro-grids can contribute to rural development: evidence from Kenya. World development, 37(7), 1208-1221.

[21] The values presented by NewClimate (2019) were used to calculate the indirect employment impacts. According to the report, a 1 MW mini-grid system in Kenya creates approximately 166 indirect short-term jobs (1 year) for professional services (86), construction (10) and other sectors (70)

[22] Dal Maso, M., Olsen, K. H., Dong, Y., Pedersen, M. B., & Hauschild, M. Z. (2020). Sustainable development impacts of nationally determined contributions: assessing the case of mini-grids in Kenya. Climate Policy, 20(7), 815-831.

[23] Calculated assuming the six-mini grids will deliver annually 2,780 MWh, which corresponds to approximately 1.4 MW of installed capacity.

[24] Dal Maso, M et al. (2020) applied the Sustainable Development Methodology developed by the Initiative for Climate Action Transparency (ICAT) to the specific case of mini grids in Kenya. The likelihood represents the probability of the impact occurring in the future as a result of the policy or action and was evaluated on a five-step scale (very unlikely: <10%, unlikely: >10% and <33%, possible: >33% and <66%, likely: >66% and <90%, very likely: >90%). An increase in the quality of education facilities and in the accessibility and quality of healthcare have been scored as likely. See Dal Maso, M et. al (2020) *Sustainable development impacts of nationally determined contributions: assessing the case of mini-grids in Kenya*. Climate Policy, 20(7), 815-831

[25] Due to the impacts of the AIDS crisis in Kenya and the past conflicts around the country, there are relatively high percentages of the poor and total population living with HIV/AIDS. Therefore, raising awareness about HIV/AIDS is seen as a potential benefit/positive impact of the project, as stated in the project documentation KPLC & REA (2015).

[26] See: IASS (2021) *Status and trends of energy development and climate action in Kenya.* Available at: https://www.cobenefits.info/wp-content/uploads/2021/07/COBENEFITS-Impulse_Energy_Climate-Action_Kenya.pdf; Njenga, M., Gitau, J. K., & Mendum, R. (2021). Women's work is never done: Lifting the gendered burden of firewood collection and household energy use in Kenya. Energy Research & Social Science, 77, 102071 and SEI (2014) *Sustainable firewood access and utilization Achieving cross-sectoral integration in Kenya.*

[27] Based on the project documentation, social inclusion and gender considerations are listed as a potential benefit/positive impact. Gender considerations would be addressed especially during consultations in identifying impacts to allow all parties affected, including women, to understand the compensation and voice their concerns. Moreover, the project ensures that marginalized groups (including youth) have equal opportunities to participate in bidding processes. Locational Resettlement and Compensation Committees (LRCCs) established during the project will comprise, among others, representatives from youth, female, and vulnerable persons. See KPLC & REA (2015) Resettlement Policy Framework. Peri-Urban and Off Grid Sub-Components. Kenya Electricity Modernization Project. Available at: http://kplc.co.ke/img/full/BqwshZ6Ph19j_KEMP%20RPF%20for%20Peri_Urban%20&%20Off_Grid%20Components%20Final%20Jan.2015.pdf

[28] Evidence of this is presented by SEI (2014) *Sustainable firewood access and utilization Achieving cross-sectoral integration in Kenya*; Julia Jung, Mark Huxham, (2018) Firewood usage and indoor air pollution from traditional cooking fires in Gazi Bay, Kenya, Bioscience Horizons: The International Journal of Student Research, Volume 11, 2018, hzy014, https://doi.org/10.1093/biohorizons/hzy014; and Ortega, N., Curto, A., Dimitrova, A., Nunes, J., Rasella, D., Sacoor, C., & Tonne, C. (2021). Health and environmental impacts of replacing kerosene-based lighting with renewable electricity in East Africa. Energy for Sustainable Development, 63, 16-23.

[29] Nyamori, S. (2019) Environmental and Social Impact Assessment (Esia) Project Report for The Proposed 60kw Mini Grid in Mageta Island, Mitundu Sub-Location, Mageta Location, Bondo Sub-County Siaya County. Available at: https://www.rerec.co.ke/images/projects/MagetaESIA/Mageta-ESIA.pdf

KPLC & REA (2015) Resettlement Policy Framework. Peri-Urban and Off Grid Sub-Components. Kenya Electricity Modernization Project. Available at: http://kplc.co.ke/img/full/BqwshZ6Ph19j_KEMP%20RPF%20for%20Peri_Urban%20&%20Off_Grid%20Components%20Final%20Jan.2015.pdf

SHE (2015) Environmental & Social Management Framework Off Grid Components. Kenya Electricity Modernization Project

[30] Power for all (2019) *Powering Jobs Census 2019: Focus on Kenya* powerforall.org/poweringjobs 2

[31] Owino, B., Asher, D. and Mulwa, M. Barriers to Uptake of Clean and Renewable Energy. *Case of Bomet and Homa-Bay Counties.* Available at: https://cuts-nairobi.org/pdf/SP-E-Research_Report-1.pdf

[32] Baek, Y. J., Jung, T. Y., & Kang, S. J. (2020). Analysis of Residential Lighting Fuel Choice in Kenya: Application of Multinomial Probability Models. *Frontiers in Energy Research*, *8*, 70.

[33] IASS (2021) *Status and trends of energy development and climate action in Kenya.* Available at: https://www.cobenefits.info/wp-content/uploads/2021/07/COBENEFITS-Impulse_Energy_Climate-Action_Kenya.pdf

[34] UN (2021) Theme Report on Energy Access: Towards the achievement of SDG7 and net-zero emissions. Available at: https://www.un.org/sites/un2.un.org/files/2021-twg_1-061921.pdf.

[35] CCG (2021) Rapid Electrification in Kenya: Progress, challenges, and practical geospatial solutions. Available at: https://climatecompatiblegrowth.com/wp-content/uploads/2021/08/5E-COP26-Policy-Brief.pdf

[36] NewClimate (2019) The role of renewable energy mini-grids in Kenya's electricity sector. https://newclimate.org/2019/11/12/the-role-of-renewable-energy-mini-grids-in-kenyas-electricity-sector/

[37] Power for all (2019) *Powering Jobs Census 2019: Focus on Kenya* powerforall.org/poweringjobs 2

9. Morocco Light-Touch Case Study: Noor Ouarzazate I Concentrated Solar Power (CSP) Plant

Project Details	Funding
Name: Noor Ouarzazate I Concentrated Solar Power (CSP) **Country:** Morocco **CIF Program Area:** Clean Technology Fund (CTF) **Bank approval:** November 2011 **Effective since:** June 2013 **Actual closing:** May 2015 **MDBs:** African Development Bank (AfDB), World Bank	**Total Value:** $854.5 million **CIF:** $97 million through the World Bank, $100 million through the AfDB **Co-financing:** $657.5 million **MDBs:** $386.5 million **Government of Morocco and private partners:** $168 million **Bilateral agencies:** $103 million **Instrument type:** Loan **Sector:** Public

Key Highlights

- Noor Ouarzazate Concentrated Solar Power (CSP) was an $854.5 million project that supported Morocco in the development of a 580 MW solar power complex. CIF contributed $97 million to this project through the World Bank and an additional $100 million through the AfDB. Financed through a public-private partnership (PPP), the project aimed to increase power generation from solar power and to mitigate greenhouse gas (GHG) emissions and local environmental impacts.
- The CIF funding was directed to Component 1 (CIF also supported the Noor Quarzazate II and III component of the four phases of the Noor Quarzazate complex). Component 1 included the development and construction of Noor Ouarzazate I, a 160 MW CPS plant that was completed in 2015, components II and III added 200MW and 150MW in 2018. Noor Ouarzazate I is the focus of this case study.

Topline Findings on Development Impacts

- **Increased access to electricity:** The project directly benefits 347,780 people per year by increasing their access to electricity and accordingly improving their livelihoods.
- **Employment:** The project had direct and indirect economic and employment opportunities including the creation of 1,977 temporary jobs created during the construction phase. During the operation phase, the plant has employed 78 permanent staff, including 38 local residents (49 percent) and 7 women (9 percent).
- **Reduced GHGs and air pollution:** The project avoided about 255,000 tCO_2e of GHG emissions in 2016, as well as 1,120 tons of NO_X emissions and 4,240 tons of SO_X emissions.
- **Improved energy security:** Long-term benefits included improved competitiveness and industrial integration, and improvements to Morocco's energy sector security resilience.

Climate Investment Context and Overview

Morocco's energy needs have been rising steadily. Electricity generation grew by an average of 11 percent per year between 2000 and 2020,[1] and the expectation is that energy demand will continue to grow rapidly in the coming years. This increase in energy demand is driven by population growth, economic development, and the country's commitment to achieve universal electricity access. In 2010, Morocco was largely dependent on imports of fossil fuels—mainly coal—to generate electricity. This dependence led to high costs, exposure to fluctuations in global energy prices, and high levels of GHG emissions.[2] In 2010, before the project development, Morocco's national electricity generation of almost 24 TWh came mostly from fossil fuels: coal (46 percent), natural gas (12 percent), and fuel oil (24 percent). Only 18 percent of the energy mix was from renewable sources: wind (3 percent) and hydroelectricity (15 percent). There was no use of solar energy resources.

To address these issues and secure the country's energy independence, in 2009 Morocco adopted its national energy strategy for 2010 to 2030.[3] Its aim was to increase the share of renewable energy to 42 percent by 2020 and to 52 percent by 2030. The strategy for achieving those targets included plans to install 2,000 MW of solar power capacity by 2020 and 4,560 MW by 2030. The Noor Solar Plan was launched to achieve the 2020 target. Ouarzazate was one of the five sites selected, with a planned capacity of 582 MW.

The total investment in Ouarzazate is estimated at $854.5 million. CIF contributed $197 million through the Clean Technology Fund (CTF) to Component 1, including $97 million through the World Bank and $100 million through the AfDB. The remaining $657.5 million came from the World Bank, the AfDB, the Agence Française de Développement (AFD), the European Investment Bank (EIB), the Kreditanstalt für Wiederaufbau (KFW), and the borrower in the form of loans. Table 1 describes the overall project budget.

Table 1. Project Components Description and Budget

Component	Description	Budget (USD)
Component 1: Financing the Initial Investment of Noor I	Development and construction of Noor Ouarzazate I	Total Appraisal: $1,235 million Total Actual: $854 million • CTF: $197 million • Borrower: $168 million • AFD: $103 million • AfDB: $133 million • EIB: $120 million • KFW: $133 million
Component 2: Cost Mitigation Mechanism	Support the sale of electricity from the project, in part by helping to offset the difference between the price at which MASEN[4] would buy electricity and the price at which it would sell it to the national electrical utility.[5] In 2015, this loan was cancelled and restructured as part of the broader Noor Ouarzazate Complex Project, providing the same support, but on more beneficial terms for MASEN.	Total Appraisal: $200 million Total Actual: $0.5 million from World Bank
Total Actual		**$854.5 million**

Project Objectives Related to CIF Financing

Component 1 was structured over four stages (Table 2). The CTF funding was allocated only for the development and construction of the first phase, Noor Ouarzazate I (Noor I).[6] Noor I is a concentrated solar power (CSP)[7] plant with a three-hour thermal energy storage system to provide dispatchable energy. The project was implemented on a build, own, operate, and transfer (BOOT) basis through a public private partnership (PPP). It was constructed by the ACWA Power Ouarzazate (APO), a consortium led by ACWA Power, and included MASEN, Aries, and TSK. The first phase also included the construction of the common infrastructure that serves all phases of the Noor Ouarzazate complex (e.g., access roads, water and electricity supply, telecommunications, security, etc.).

This first phase paved the way for subsequent phases of the complex by facilitating construction of common infrastructure and laying the groundwork for future construction. CTF support for Noor I also facilitated subsequent phrases of the project by helping participants to learn about CSP technology. In addition, the low-cost debt provided by CTF and other international financial institutions reduced the levelized cost of electricity for phase 1 by almost 25 percent compared with financing available from banks.[8]

Table 2. Phases of Noor Ouarzazate Complex

Noor Ouarzazate Plant Phases	Technology	Capacity (MW)	Status of Implementation[9]
Noor Ouarzazate I (Noor I)	CSP	160	Completed and commissioned in 2016
Noor Ouarzazate II (Noor II)	CSP	200	Completed and commissioned in 2018
Noor Ouarzazate III (Noor III)	CSP	150	Completed and commissioned in 2018
Noor Ouarzazate IV (Noor IV)	Solar PV	72	Completed and commissioned in 2018

Without this project, the government would have produced electricity using fossil fuel sources (mostly from coal), leading to increased imports of fossil fuels, more air pollution, and higher emissions.

In addition to the Noor I, CIF (through CTF) funded two other projects in Morocco: the Clean and Efficient Energy Project (US$23.95 million from CIF) and the One Wind Energy Plan (US$125 million from CIF).[10] These projects are not covered by this case study.

Project stakeholders

The key stakeholders of this project include the Moroccan Agency for Sustainable Energy (MASEN), the private sector sponsor ACWA Power, and National Office of Electricity and Potable Water (ONEE). The project developer was ACWA Power Ouarzazate (APO), a consortium that was led by MASEN, ACWA Power, and TSK.

MASEN is a special purpose energy company created by Law 57-0918 in 2009, as part of the Moroccan Energy Strategy. As the project implementing agency, MASEN was responsible for the management of technical, procurement and financial aspects of the project. MASEN mobilized and secured the required funds from financial donors and lent them to APO. It also acted as the intermediary, purchasing electricity from APO and selling it to ONEE. To support the bidding process, MASEN appointed technical, legal, financial, and social and environmental safeguard advisors. It also established an internal organization to monitor the performance of APO. ONEE is responsible for the purchase of renewable electricity produced from MASEN projects though long-term power purchase agreements (PPAs). ONEE also generates its own electricity from coal, gas, and wind power plants.[11]

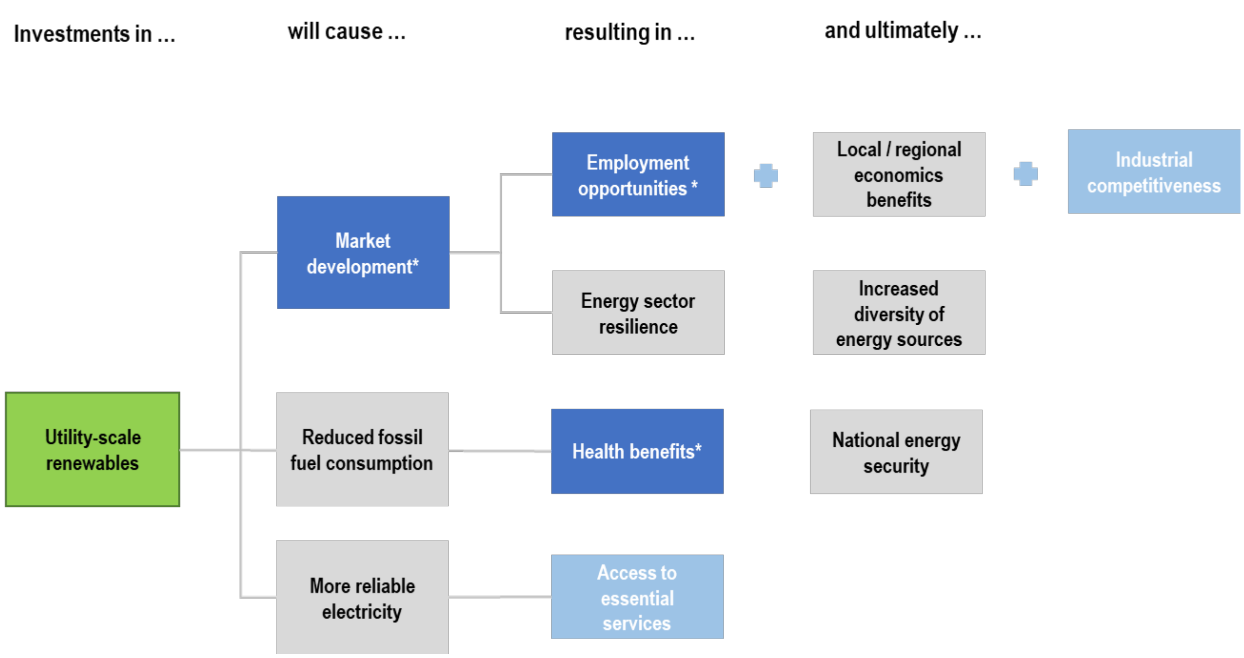
The consortium led by ACWA Power and including ARIES and TSK from Spain was selected as the contractor of Noor I. APO was created in November 2012 under the name of ACWA Power Ouarzazate as the Solar Project Company (SPC), with 75 percent of shares held by the consortium led by ACWA Power and 25 percent held by MASEN through its subsidiary MASEN Capital (MASEN K.) ACWA Power is a Saudi Arabia-based private developer, investor, co-owner and operator of power generation assets. APO issued the engineering, procurement, and construction (EPC) contract to construct Noor I to the consortium of Acciona, TSK, and Sener under a turnkey EPC contract.

Development Impact Pathways and Case Study Focus

This light-touch case study examines the development impacts of the CTF funding of the Noor I Project. The evaluation team built their analysis from the large number of existing project documents.[12] The main development impacts assessed in this case study included access to essential services, employment opportunities, health and safety benefits, energy sector security and resilience, and competitiveness and industrial development.[13]

Figure 1 provides an overview of development impacts (DIs) targeted and achieved by Noor I, as identified through a review of documents shared by project stakeholders.

Figure 11. Impact Pathway for Noor Ouarzazate I Concentrated Solar Power (CSP) Project[14]



*These DIs are included in the project documents and have an associated metric.

The figure distinguishes between three types of DIs in relation to this case study: The **dark blue** boxes indicate the DIs that are quantitatively addressed in this case study: employment opportunities, health benefits from the avoided local air pollutants (NOx and SOx), and market development.[15] The **light blue** boxes indicate the DIs that are qualitatively addressed in this case study: access to essential services and industrial competitiveness and integration.

The **grey boxes** indicate the DIs that are implied in literature, but not assessed in this case study because they are either too long-term to assess currently, and/or would require additional research and analysis:

- Energy security and sector resilience: The project would need to be of greater scale to affect the overall power sector in Morocco.
- Reduced fossil fuel consumption: Insufficient evidence from the reviewed documents to assess this impact. [16]
- Local/regional economic benefits: Assessment would require additional analysis, including modeling, to quantify regional economic benefits.

Development Impacts: Quantified Results to Date

Employment opportunities

The project resulted in the creation of direct and indirect job opportunities, with 1,977 temporary jobs created during the construction phase and 78 permanent jobs during the operation phase. Although the recruitment policy of the Noor I Project sought to maximize the number of local workers, this target was not fully achieved due to the mismatch between the skills of the local population and the technical requirements of the created positions. On average, nearly 70 percent of the workers were Moroccan, 35 percent of whom were local workers from the region (Ouarzazate and Ghessate). In the operation phase, of the 78 jobs, 38 were locals (49 percent).[17] Only 70 of the 1,977 jobs created during the construction phase went to local women. This gap was attributed to social and gender norms and to a lack of technical skills. In the operation phase, seven women have been employed on the operations and maintenance staff (10 percent of the total staff) in positions including catering, administration, and quality control to health and safety, welding, and topography.

In addition to the creation of direct job opportunities, the project also enabled indirect employment opportunities for women through corporate social responsibility (CSR) activities. Women in the impacted communities requested training in traditional home-based activities including weaving, knitting, and embroidery. Accordingly, MASEN created a partnership with the Ministry of Craft in Morocco to initiate training activities for women. MASEN pledged to fund trainers, transportation, work materials, and insurance costs.[18] Infrastructure development in the local community (e.g., access to roads) will also provide improved access to economic opportunities.

Health benefits from the avoided local air pollutants

The actual amount of avoided NO_X emissions at the completion of the project was estimated to be 1,120 tons, above the target of 1,000 tons. Similarly, the actual amount of avoided SO_X emissions at the completion of the project was estimated to be 4,240 tons, above the target of 4,000 tons. These emissions would have otherwise been generated by fossil-fuel powered plants, with associated health impacts from the air pollution. The avoided NOx and SOx emissions were valued based on the actual emission savings derived from the ONEE dispatch study and unit prices for emissions that were adapted to the Morocco context from a European Commission study.[19] Table 3 provides the economic/monetary impact of NOx and SOx emissions in the Moroccan context.

Table 14. Economic/monetary Unit Impact of NOx and SOx Emissions in the Moroccan Context

Pollutant	Morocco Price ($/ton in 2010)
NOx	1,370
Sox	1,380

The ONEE dispatch study shows that Noor I operating at 160 MW capacity would displace 68 GWh of coal generated electricity, 54 GWh of natural gas generated electricity, and 249 GWh of fuel-based electricity. Table 4 presents the corresponding values of avoided emissions.

Table 15. Value of Avoided Emissions after Implementation of the Noor Ouarzazate I CSP Plant

Fuel used in electricity generation	Value of CO_2 avoided emissions ($ million /year)	Value of other emissions avoided emissions ($ million /year)
Coal	2	1.3
Natural Gas	0.7	0
Fuel oil	4.4	5.6
Total	**7.1**	**6.9**

Market development

The project has gradually expanded private sector investment in renewables in Morocco. The PPP structure stimulated large private sector participation and reduced the risk premium of these types of projects. The low-cost debt from CTF and other international financing institutions for Noor I also reduced the project costs by around 20 percent compared with financing from commercial banks in Morocco.[20] In the PPP structure, the Moroccan government shouldered several risks that are usually taken by private sector through the provision of common infrastructure and the assumption of financial and technological risks. The PPP structure reduced the risk premium of the project while ensuring that the cost per kWh was minimized. A streamlined tender process was used to support the following goals:

- Reduce the costs to developers through transparent tender processes and clear procurement rules, and the availability of background technical, social and environmental studies, and
- Reduce the costs of funding for the project by securing financing from several international financial institutions at concessional rates.

This PPP approach created a comfortable investment climate for the private sector despite the high technological risk of the project and was further adopted for Noor II and Noor III.[21] The project targeted private capital mobilization of $120 million and achieved a value of $168 million. With this successful scaling-up of CSP, the technology became more economically viable with lower capital costs and therefore more attractive to the MENA region.

Table 5. Summary of Quantified DI Benefits Assessed

DI	Included in original project documents?	Metric /KPI	Method of assessment
Employment (job creation)	Yes	Number of permanent jobs Number of temporary jobs	World Bank Implementation Completion and Results reports
Health benefits	Yes	Avoided local air pollution (tons)	World Bank Implementation Completion and Results reports
Market development	Yes	Private capital mobilized (USD)	World Bank Implementation Completion and Results reports

Other Implied DI Impacts (Qualitatively Assessed)

Access to essential services

The number of direct project beneficiaries reached 347,780 people per year. These individuals benefit from increased electrification rates in rural and semi-urban areas within the project region with both better and cleaner electricity. MASEN and APO also developed and implemented a CSR strategy and a general, voluntary social action plan focused on impacted communities. This strategy targeted programs to support local development activities.[22] The targeted actions for the Noor I Project included the organization of mobile medical caravans in the Ghassate Rural Municipality (a commune in Ouarzazate Province), road maintenance, and welding training programs in partnership with the regional branch of the Vocational Training and Labor Promotion Authority (OFPPT).[23] MASEN also built a secondary-level girls school in Ghassate that accommodates around 100 students, provided minibuses, and distributed school supplies and equipment among students.[24] Finally, the new roads constructed by the project stimulated the economy in neighboring communities in what are considered lagging regions in Morocco.[25] Site construction activities also facilitated the work of subsequent phases of the Noor Ouarzazate Complex.

Industrial competitiveness and integration

The project had a positive impact on industrial integration and competitiveness by involving local industries to provide local equipment, tools, and a variety of services during the construction phase, with continued maintenance and service provision contracts during the operation phase. The rate of industrial integration of Moroccan companies in the construction and operation phases of Noor I reached 35 percent, exceeding the planned value of 30 percent. These services included metallurgy, electrical cabling, civil engineering, and other construction related services, as well as installation and maintenance services during the operation phase. In addition, the launch of new industrial activities such as the production of torque tubes strengthened the high-tech capacity of local firms through knowledge collaboration and association with foreign firms.[26]

Other Implied Qualitative DI Impacts (Not Assessed)

Energy security and sector resilience

Noor I was intended to improve the resilience of the energy sector in Morocco and create a reliable electricity source. However, the scale of the project (about 1.94 percent of the installed electric energy capacity in Morocco) is not large enough to significantly affect the overall power sector in Morocco and was not assessed in the reviewed documents.[27] Nevertheless, the project was part of Morocco's first utility-scale solar energy complex, and it made Morocco a frontrunner in CSP, with positive implications for the development of CSP technology in the Middle East and North Africa (MENA) region. It is estimated that the learning curve generated from the Noor Ouarzazate Complex can reduce the global costs of CSP projects by 3 percent through the demonstrated viability of CSP technologies.[28] The project was also able to trigger significant cost reductions through economies of scale and reduced the competitiveness gap between CSP and other renewable technologies.[29]

The project supported Morocco's aims to increase energy security by diversifying its energy sources, reduce its reliance on imported fossil fuels, and increase the share of energy from renewable sources. At the same time, the project encouraged private sector participation in low-carbon development in the energy sector through the PPP approach. CSP technology allows better integration of the generated electricity with the interconnected national grid and better flexibility to produce energy during the peak demand evening hours. Noor I, with an installed capacity of 160 MW, generates about 400 GWh of electricity per year. The Noor Ouarzazate Complex overall, with a combined total of 510 MW of CSP and 72 of solar PV of installed capacity, thus dramatically expanded solar power in Morocco, though the country missed its target of reaching 2,000 MW of solar power capacity by 2020. Across Morocco, at the end of 2021, total installed solar capacity was 831 MW, with CSP making up 13.3 percent of the country's total power generation capacity, and solar PV, 7.2 percent.[30] Solar projects nationwide fed 1,802 GWh into the national grid in 2021, or 4.4 percent of all electricity. Morocco's total renewable capacity at the end of 2021 was 4,067 MW, more than triple what it was in 2000. By 2030, Morocco aims to have renewables make up 52 percent of its installed capacity, which would require adding 4,560 MW of solar, 4,200 MW of wind, and 1,330 MW of hydropower capacity from 2018 levels.[31]

Reduced fossil fuel consumption

The Noor I Project replaced fossil fuels consumption in energy generation with a clean energy source. According to the project appraisal document, the plant would displace 68 GWh per year of electricity from coal power, 54 GWh of gas-fired plants, and 249 GWh generated from oil products.[32] However, the project documents did not provide operational versions of these values, nor were baseline estimates provided. Given that a variety of fossil fuels are used to generate electricity, the evaluation team back calculated to amounts of fuels displaced by the project activity based on the amount of electricity generated. From this method, it is roughly estimated that the project will result in reduced fossil fuel consumption equivalent to 34,800 tons of coal, 4.91 million m^3 of natural gas, and 74,700 liters of fuel oil.

Local/regional economic benefits

The project has reduced the strain on public finances by lowering the subsidy from the Moroccan government for the Noor I Project from $98 million to $31 million per year as a result of the international financial support to the complex.[33] Since the project required the acquisition of land belonging to the Ait Ougrour Toundout community, the community requested that the compensation be used to fund local development projects. These projects were identified and implemented by the Department of Rural Affairs (DAR). DAR organized several meetings with community representatives to understand their needs. This process resulted in a list that included irrigation facilities, drinking water supply, sociocultural projects, infrastructure projects, cropland protection, health infrastructure projects, and education related projects. By the end of January 2018, MAD 28 million (approximately US$3 million) was allocated to these projects. This development impact was unplanned, but it is a good model for future projects to emulate.

Enabling Conditions for Growth to Date

Several factors positively affected the implementation and outcomes of the project.

Ensuring a strong commitment at the country/state level

The strong commitment to this large-scale energy project was a key factor in its success. During the preparation phase, the Moroccan government's commitment combined with MASEN's leadership provided a solid institutional basis for success and it was maintained throughout the following phases of the Noor Ouarzazate Complex.

The development of a national energy strategy with specific objectives for renewable energy generation and reinforcement of the transmission network was a starting point to facilitate the development of the project. This strategy was enforced by the legal, institutional, and regulatory framework for the development of renewable energy projects in Morocco (Law 16/2008) and for the trade of electricity produced from renewable energy projects in the local market (Law 13/2009 and Law 54/2014). The government also established several other public agencies to better organize and structure renewable energy project developments. One example is MASEN, whose mission was reinforced and empowered by Law 37/2016 during project implementation. MASEN was also able to ensure proper coordination between different governmental departments to increase efficiency and avoid unnecessary delays for the project.

Environmental and social safeguarding advisors

MASEN appointed technical, legal, fiduciary, and social and environmental safeguards advisors to provide support in the bidding process and for the preparation of legal documents. This step accelerated the project start and was critical for the effective implementation of the project, particularly since this was MASEN's first project of this kind. These advisors ensured MASEN was aware of the technical, legal, financial, and social and environmental safeguards that need to be included in the bidding documents to improve the effectiveness of project implementation.

Public-private partnership (PPP)

The PPP approach was useful in reducing the project's risk and provided a more attractive investment climate for the private sector, given the high technological risk of the project at that time. This approach also was replicated in other CSP projects funded by the World Bank in the MENA region. For example, Jordan's Ma'an public sector project (to construct parabolic trough and solar tower CSP plants totaling 225 MW) has been replaced by the public-private partnership model.[34]

Barriers to Noor Ouarzazate I CSP Plant in Morocco and Realizing DIs

There were some barriers that affected the project during its preparation and implementation phases. During the project preparation phase, the project costs and pool of bidders were uncertain, and key project risks could not be fully assessed as the competitive bidding process was not completed, and negotiations of key project documents had not taken place.

During the implementation phase, some external factors caused a small delay. These factors included climate-related incidents (heavy windstorms and heavy rains) that damaged the field and interrupted the course of work. Also, the mirrors' efficiency was reduced during the first year of operation due to dust from the Noor II and Noor III construction sites. This impact was mitigated by the purchase of additional cleaning vehicles.

Women's participation in the project operation phase was considered low (around 10 percent of the workforce) as a result of underdeveloped skills and social and gender norms as women in Morocco are not traditionally engaged in civil works. Most of the women employed during the construction phase were involved in cooking and cleaning activities.

Regional Replication of the Project in the MENA Region

The CTF fund endorsed a $750 million investment plan to support the development of 1 GW of CSP generation capacity and associated transmission infrastructure in five MENA countries (Morocco, Egypt, Algeria, Jordan, and Tunisia). Morocco was one of the first countries to make significant progress with the construction of Noor I followed by Noor II and Noor III, but some countries have fallen behind their implementation schedule (e.g., Egypt's Kom Ombo's CSP project and Tunisia's Akarit project). One of the main reasons for delay of CSP implementation in those countries was the high cost of CSP investment that leads to high incremental costs.[35] There were also challenges due to other political and economic disruptions in the region.[36]

Future Opportunities for Realizing DIs

Optimization of technical design specifications

Work on the Noor Ouarzazate Complex found that optimized technical design with flexibility in the technical specifications gives more room for bidders to propose an optimized plant design to meet capacity and thermal storage requirements. For example, the design specifications of Noor II and Noor III were more flexible than Noor I in terms of specifying the minimum required amount of peak hour generation rather than specifying a prescriptive design.

Legal agreements in upfront procurement documents

Negotiations during the procurement phase of large-scale renewable energy projects can be time-consuming. For Noor Ouarzazate I, some delays occurred during the procurement phase due to negotiations. Accordingly, MASEN included legal agreements in upfront procurement documents in the subsequent phases to shorten the duration of negotiations.

Long-term social impacts

MASEN and APO's CSR strategy for the local population project resulted in several positive impacts and created working opportunities for women. However, permanent services that enable residents, especially women, to participate more actively in the daily working activities would be further appreciated by the locals. For example, establishing daycare centers would enable women to participate more actively in jobs and would create an enabling environment for women to work.[37]

Enhanced engagement of women

For future projects, women in the neighboring communities can be trained to engage in economic activities around the plant's construction activities. The activities can provide an important economic supplement to families. Available opportunities are likely to be unskilled manual work including the provision of services such as washing clothes or cooking and being the providers of the food services that are used to prepare the food for the construction crews.[38]

Future CTF projects

The Noor I Project can be replicated in other countries/regions. Indeed, country/state level commitment accompanied by a facilitating institutional framework and regulations are key factors to encourage investments in renewable energy projects. This facilitating framework included a national strategy with clear objectives, legal and regulatory frameworks that underpinned the strategy and renewable energy project developments, and the establishment of a dedicated, independent energy agency (MASEN) as implementing authority.

It is also important to assess the capacity needs of the local stakeholders involved in the project operations, and to provide the necessary capacity building, whether on the legal, technical, financial, social, or environmental side. This was a part of MASEN's activities to build capacities in renewable energy sector and was a key enabling condition for the growth and success of the project and the subsequent CSP projects in Morocco. This approach will ensure the sustainable operation of similar types of projects in the future.

Finally, the PPP financial approach was found to be successful for these types of projects in developing countries because it alleviates technological and financial risks associated with new and technologically uncertain project developments. As mentioned previously, it was further adopted in other countries in the MENA region (e.g., in Jordan) because of its success in the Moroccan context.

Future Research

To further assess the DIs associated with the Noor I project, additional research would be required to provide more qualitative and/or quantitative results in the following areas:

- Assessing the project's impacts on energy sector resilience and electricity reliability. Assessing this impact requires coordination with MASEN and ONEE—taking into consideration the demonstration and replication impacts of the project on the national and regional context.
- Impacts of the project on reducing fossil fuel consumption. This information would also support the assessment of the improvement of overall air quality and the related positive health impacts due to reduction in NOx and SOx emissions and other pollutants (e.g., PM_{10}, organic carbon).
- Assessing the project's local/regional economic benefits. These benefits could entail lower electricity bills, increased job creation and income sources, impact on GDP, gross value added, and turnover rates (to encourage private investments).

Endnotes

[1] See International Energy Agency (IEA) statistics for Morocco: https://www.iea.org/countries/morocco.

[2] World Bank (2011). Project Appraisal Document on a proposed loan for the Ouarzazate I Concentrated Solar Power Plant Project. Available at: https://documents1.worldbank.org/curated/en/510081468276309449/pdf/09725281.pdf.

Also see IEA statistics for Morocco: https://www.iea.org/countries/morocco.

[3] The renewable energy strategy aimed to: i) increase electricity generation from renewable energies; ii) strengthen supply security and energy availability; and iii) generalize access to electricity (rural areas) and reasonable costs.

[4] MASEN: Moroccan Agency for Sustainable Energy, a special purpose energy company created by Law 57-0918 in 2009, as part of the instruments to achieve the Moroccan Energy Strategy

[5] ONEE: National Office of Electricity and Potable Water in Morocco.

[6] Other funding agencies included the European Investment Bank (EIB), Neighborhood Investment Facility (NIF) of the European Union (EU), German Development Bank (KfW) and the German Ministry of Environment (BMU).

[7] CSP technology was preferred over photovoltaics (PV) due to its energy storage potential, which allowed for better integration of the generated electricity with the national grid, as it could help meet demand during peak hours in the evening. This was also seen as an opportunity for Morocco to become a leader in CSP.

[8] Joint AfDB–World Bank submission Document (2017), Morocco: Noor-Midelt Phase 1 Concentrated Solar Power Project. Available at: https://pubdocs.worldbank.org/en/930461531492489703/1807-XCTFMB107A-Middle-East-and-North-Africa-region-project-document.pdf

[9] Renewables Now (2018). Morocco to complete Noor Ouarzazate solar complex by mid-2018. Available at: https://renewablesnow.com/news/morocco-to-complete-noor-ouarzazate-solar-complex-by-mid-2018-602259/

Power Technology (2020). Noor Ouarzazate Complex. Available at: https://www.power-technology.com/projects/noor-ouarzazate-solar-complex/

[10] See the CIF country page for Morocco: https://www.climateinvestmentfunds.org/country/morocco

[11] ONEE has to transfer all renewable generation assets to MASEN by 2021 according to the Law 38 for year 2016, with the exception of pump storage hydro plants.

[12] Due to the time that elapsed since the project finished, changes in roles of key stakeholders and stakeholder evaluation fatigue, the evaluation team was unable to conduct interviews for this project. However, the significant volume of information available allowed for this comprehensive new analysis from the development impact perspective.

[13] The following DI KPIs were used in the ICR report[13] to measure the project's actual achievements: (1) Installed CSP (MW); (2) Electricity production (GWh); (3) Avoided local air pollution (tons of NO_x and SO_x annually); (4) Avoided GHG emissions (tons of CO_2 annually); (5) Direct project Beneficiaries and female beneficiaries.

[14] Aligns with Figure 1 (Theory of Change Diagram) in the Implementation Completion and Results Report (P.8) by the World Bank (Report no. ICR 00004271).

[15] World Health Organization. Air Quality and Health. Available at: https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/health-impacts/types-of-pollutants

[16] The project documents did not provide values for reductions in fossil fuel consumption, nor were baseline estimates provided. A variety of fossil fuels are used to generate electricity, including coal, fuel oil and natural gas. The absence of information in the project files makes it difficult to back calculate the reductions in fossil fuel sources that resulted in reported NOx and SOx emissions reductions. Using a simplifying assumption, the evaluation team back calculated to TOE based on the amount of electricity generated. Based on this method, it is estimated that the project will result in reduced fossil fuel consumption of approximately 34,394 TOE, which is equivalent to 40 million m^3 of natural gas or 35.4 ktons of Heavy Fuel Oil. However, it is a rough estimate based on incomplete information.

[17] ADB (2019). Noor Ourzazate Solar Complex Project – Phase I: Project Completion Report. African Development Bank. https://www.afdb.org/en/documents/document/morocco-noor-ouarzazate-solar-complex-project-phase-i-noor-ouarzazate-i-power-plant-pcr-107754.

[18] Source: ESMAP, 2018, *Getting to Gender Equality in Energy Infrastructure: Lessons from Electricity Generation, Transmission, and Distribution Projects*. Available at: https://openknowledge.worldbank.org/handle/10986/29259

[19] EC ExternE study (ENG1-CT2002-00609). See also the Project Appraisal Document for Noor Ouarzazate I.

[20] The World Bank (2015) Article: Morocco to Make History with First-of-Its-Kind Solar Plant. Available at: https://www.worldbank.org/en/news/feature/2015/11/20/morocco-to-make-history-with-first-of-its-kind-solar-plant

[21] AfDB, EIB, The World Bank (2017) Multilateral development banks collaboration: Infrastructure investment project briefs: Morocco Noor Ouarzazate Concentrated Solar Power Complex. Available at: https://ppp.worldbank.org/public-private-partnership/sites/ppp.worldbank.org/files/2022-02/MoroccoNoorQuarzazateSolar_WBG_AfDB_EIB.pdf

[22] 100 targeted projects/actions were implemented by MASEN through the period between 2010 - 2017

[23] Local people would have preferred a permanent health center with skilled medical staff. Women especially expressed a strong preference for constructing health and maternity centers equipped with skilled medical staff. Source: ESMAP, 2018, *Getting to Gender Equality in Energy Infrastructure: Lessons from Electricity Generation, Transmission, and Distribution Projects*. Available at: https://openknowledge.worldbank.org/handle/10986/29259

[24] Ibid

[25] Renew. Energy Environ. Sustain. 6, 8 (2021) A. Laaroussi et al., Published by EDP Sciences. Available at: https://doi.org/10.1051/rees/2021008

[26] Rees Journal, 2021, Impact study of NOOR 1 project on the Moroccan territorial economic development. Available at: https://www.rees-journal.org/articles/rees/pdf/2021/01/rees210010.pdf

[27] The World Bank (2018) Implementation Completion and Results Report on a Loan in the amount of US$200 Million to the Moroccan Agency for Sustainable Energy for the Ouarzazate Concentrated Solar Power Project (P122028).

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10. Nepal Deep-Dive Case Study: Development Impacts of Expanding Biogas Generation

Project Details	Funding
Name: Extended Biogas Project **Country:** Nepal **CIF Program Area:** SREP **Bank approval:** August 2014 **Effective since:** November 2014 **Closed:** August 2021 **MDB:** World Bank	**Total Value:*** Planned: $14.8 million; actual: $7.75 million **CIF:** Planned: $7.9 million; actual: $4.2 million **Co-financing**:* Planned: $6.9 million from Government of Nepal; actual: $3.6 million **Instrument type:** Grant **Sector:** Public **Note: The project also leveraged at least $8.4 million in private investment. Consistent with project documents, private sector funds are excluded from the total value. The difference between planned and actual cost is attributable to several challenges in the project, including delays due to the COVID-19 pandemic.*

Key Highlights

- The Extended Biogas Project supported market-led approaches to commercially viable, large-scale off-grid biogas production from municipal and commercial waste using public-private partnership approaches. The project addressed barriers to widespread adoption of biogas through a combination of financial and technical assistance.
- As of August 2021 (project close), 194 large-scale biodigesters were installed ranging in size from 12 to 200 m^3; and 11 very large biogas projects with capacities around 3,000–4,000 m^3 were on the verge of completion. Five of these were municipal plants and the others were commercial plants.
- The biogas is used for a variety of applications, including thermal (industrial heat) applications, as a replacement for LPG in restaurants and hotels, and electricity generation. Digestates produced as a byproduct of biogas production can also be sold to the market as organic fertilizers to replace chemicals fertilizers.

Topline Findings on Development Impacts

- **Biogas market development:** The project led to large matching investments in the biogas market from the public sector ($6.9 million committed, $3.6 million disbursed); in addition, the project leveraged private sector investment of at least $10.68 million. The project contributed to the development of a local large-scale biogas industry in Nepal through commercially viable business models, raised awareness about the biogas market, and promoted biogas adoption. It also trained 40 companies in evaluating and appraising large biogas projects.
- **Local job creation:** Biogas plants create an estimated 20 jobs in municipal solid waste-to-energy plants and 50 jobs in commercial biogas plants. In the construction phase, biogas projects can temporarily employ up to 200 people.

- **Energy security:** The biogas produced from the SREP-supported biogas projects replaced an estimated 600,000 liquefied petroleum gas (LPG) cylinders, equivalent to more than $5 million of import substitution.
- **Reduced cost of waste management:** Municipalities and biomass suppliers could realize waste management cost savings; in addition, farmers can earn additional income, based on the volume of animal biowaste they provide to biogas plants, averaging an estimated $188 per month.
- **Access to reliable energy:** As of 2021, 275 businesses gained improved energy access through the project. Improved energy access for households was not monitored, but the replacement of fossil fuels with biogas makes heating/electricity more affordable for the local population, with estimated energy cost savings of 25–30 percent.
- **Reduction of greenhouse gas emissions:** The SREP-funded biogas projects have avoided an estimated 90,754 tCO_2e annually, translating to 1.815 $MtCO_2e$ over a 20-year lifetime of the biogas plants. A Program of Activities under the Kyoto Protocol has been designed to bundle the SREP-funded projects, as well as future projects, to mobilize carbon financing.
- **Reduction of land, air, and water pollutants and improved soil quality:** The waste used in biogas plants is estimated to reduce landfill waste on site by at least 50–60 percent. The project also supported the production of more than 88,000 tons of organic fertilizer that farmers can use instead of chemical fertilizers, improving soil quality and yields and reducing fertilizer import bills by up to $34 million.
- **Health benefits:** Indoor air quality improvements are expected to result from substituting harmful cooking fuels with biogas, in turn reducing adverse health impacts.
- **Benefits to local women:** The project reduced the time needed to collect fuel wood, cook, and clean, activities which are often done by women. It also provided employment opportunities for women, particularly related to waste sorting.

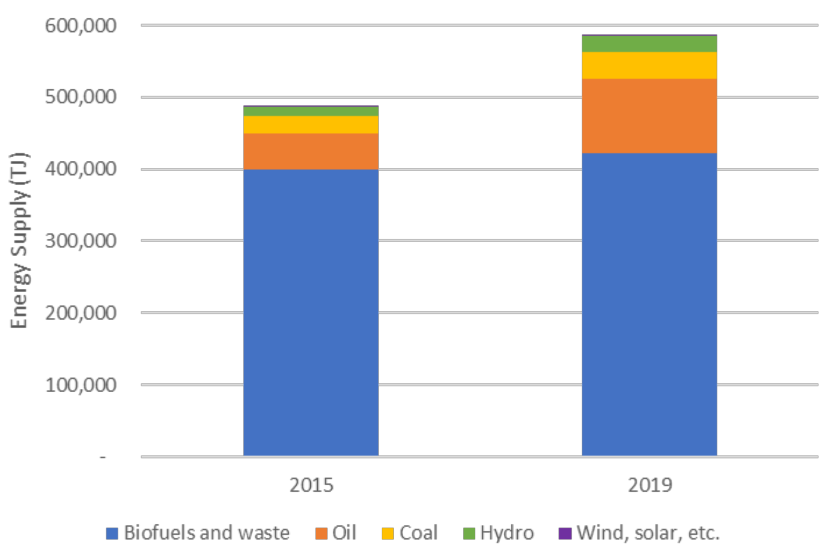
Climate Investment Context and Overview

Nepal's economy grew by an average of 3.9 percent per year between 2009 and 2019, and its population, by an average of 1.4 percent. However, the country still faces significant challenges in achieving sustainable growth.[1] Its income per capita remains just US$1,220 as of 2021,[2] a quarter of the population lives below the national poverty line, and Nepal ranks only 143rd out of 191 countries on the 2021/2022 Human Development Index.[3] At the time of the project appraisal, it ranked 141th worldwide for the overall quality of its infrastructure. Though Nepal is slowly urbanizing, 79 percent of the population still lived in rural areas as of 2021,[4] typically in mountainous regions with inadequate infrastructure. Energy consumption per capita is very low (0.2 MWh per capita in 2019).[5]

Nepal's energy crisis is a major barrier to development. The country faces increasing energy demand and insufficient supply due to reliance on fuel imports, inadequate infrastructure, lack of exploitation of renewable energy sources, and other geographic and geopolitical issues.[6] The energy crisis has highlighted the need to further develop and diversify domestic electricity generation options. Nepal has thus prioritized on-grid electricity production and delivery in addition to modernizing its off-grid electricity sector, which serves a large part of the population. It has introduced a renewable energy subsidy to develop the renewable energy sector and encourage poor households to utilize renewable energy sources.[7] It has also introduced a rural energy policy to support poverty reduction and environmental conservation by ensuring access to clean and reliable energy in rural areas.[8]

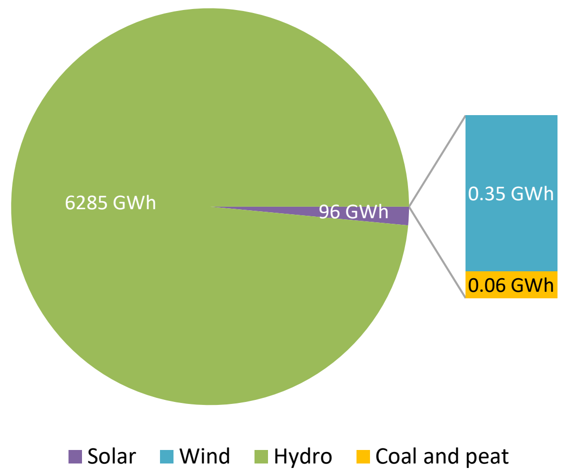
From 2015 to 2019, Nepal increased its energy supply by 20 percent, though most of this increase came from an expansion in the oil supply. A driver of this increase is the expansion of demand from the commercial and industrial sectors for fuel for diesel generators to deal with power shortages and provide backup power. As shown in Figure 1, as of 2019, 72 percent of Nepal's total energy supply (heat and electricity) was derived from biofuels and waste, followed by oil (18 percent), coal (6 percent), hydropower (4 percent) and wind/solar (0.005 percent).[9] The use of biofuels/waste is primarily for heat from the traditional consumption of firewood. Otherwise, Nepal relies on imported fuels, especially from (or via) India, making it vulnerable to international price fluctuations. Nepal's electricity network is powered almost entirely by hydropower (Figure 2), which also relies on technological and equipment imports from India.[10] Electricity provided through the grid is only a very small share of the total energy supply, for example the 6,381 GWh of electricity is equivalent to around 23,000 TJ, or around 4 percent of the total energy supply. Electricity access is an important issue, although it should be noted that many businesses and others self-generate using diesel generators. Overall, the Nepalese energy system is still heavily based on traditional sources (biomass), and there is significant progress to be made to access modern energy supplies and extend electricity access and reliability.

Figure 1. Energy Supply in Nepal, 2015 and 2019



Based on data from IEA: https://www.iea.org/countries/nepal.

Figure 2. Electricity generation in Nepal (GWh), 2020



Based on data from: IRENA (n.d.). Electricity generation (GWh) by country/area, technology, grid connection and year. Available at: https://pxweb.irena.org/pxweb/en/.

Waste collection efficiency rates in Nepal remain quite low, with only around 50 percent of total waste collected.[11] In the absence of a proper waste management system and sanitized landfills, collected waste is usually openly dumped, causing environmental and health issues for communities. Inadequate enforcement of pollution control laws leads to most industrial and agricultural waste being disposed of in land and waterbodies, leading to air and water pollution.

The introduction of modern large-scale biogas production provides an opportunity to address both the need for more energy and the waste management and pollution issues in Nepal. For private enterprises and municipalities, it is a chance to incorporate the production of thermal/electric energy from their organic waste into their ongoing business processes. It also supports Nepal in achieving its long-term strategy for net zero emissions by 2030, by increasing clean energy generation and reducing greenhouse gas (GHG) emissions in the residential sector by replacing liquefied petroleum gas (LPG) with biogas.[12]

By capturing methane from decomposing organic waste, biogas can be used directly in industrial thermal heating processes such as steam production, and for electricity production, using retrofitted generators for both diesel and biogas use. It can also be bottled or converted to biofuels. Large-scale biogas production has synergies with agricultural production, as the organic waste streams from agriculture, such as waste from cattle, poultry, and pig farms are an input for biogas production. More broadly, synergies are also possible with waste streams from the beverage industry, fruit processing, hotels and restaurants (food waste), and municipal solid waste (MSW).[13] Furthermore, the byproduct of biogas production, digestate, can be used and sold as organic fertilizer to replace chemical fertilizers.

Purpose and Scope of the Case Study

This case study evaluates the development impacts (DIs) of expanding off-grid biogas generation in Nepal. The case study results are intended to help strengthen CIF's programmatic approach to supporting energy development, while offering lessons that can help maximize DIs in Nepal and other developing economies.

The potential of biogas to meet Nepal's energy needs has long been recognized, but uptake was limited prior to the Extended Biogas Project. In 1992, Nepal's Alternative Energy Promotion Center (AEPC) implemented a government program to support the development and deployment of household sized biogas plants, using animal manure as the energy source.[14] This was adopted by 262,000 households, but these systems were based on older low-efficiency technologies and were very small, with a generation capacity of less than 20m^3. Modern, commercial-sized systems did not then exist in Nepal. Furthermore, the AEPC had limited experience with large-scale biogas digesters and generation of electricity from biogas and lacked a network of business consultants familiar with large biogas technology. Commercial lenders also did not have the awareness or appetite to engage in this sector, given that it was a new and somewhat risky technology in Nepal. Other key barriers to biogas production in Nepal prior to the Extended Biogas Project included low awareness of biogas; lack of in-country technical knowledge (often expertise from India or elsewhere was brought in); complex administrative and financial procedures to develop biogas projects, especially for front-runner developers; and difficulties acquiring land to site projects.

The Extended Biogas Project aimed to address these barriers and support the development of a commercial market for large-scale biogas projects by reducing investment risks through grant funding, institutional capacity building, and awareness raising.

From 2014 to 2021, the World Bank and CIF supported the Extended Biogas Project in Nepal through the Scaling Up Renewable Energy Program in Low Income Countries (SREP). The total budgeted project cost was $14.8 million, of which $7.9 million was a CIF grant. As shown in Table 1, CIF supported a technical assistance component ($1.5 million), financing of investments in biogas ($6.23 million), and a project management support component ($0.17 million); $6.9 million in co-financing for the biogas plants was provided by the Government of Nepal (GoN) for financing of investments (component 2). Several delays occurred in the project, for multiple reasons, most notably the COVID-19 pandemic, that resulted in only $4.2 million of the CIF funds, and a total of less than $7.8 million, being disbursed.[15] Some activities are ongoing under another SREP funded Minigrid Project which, at the request of the Government of Nepal (GoN), is being restructured to create a separate component for biogas activities.

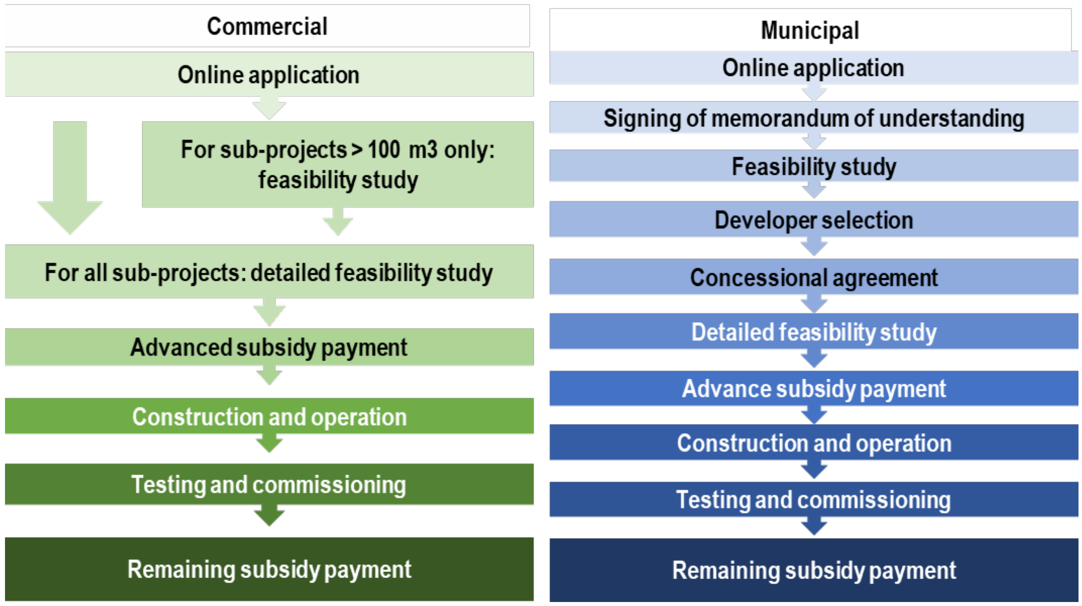
CIF and the AEPC each covered 20 percent of the costs of biogas projects, while the remainder was covered by investments from developers through equity and/or debt. To help close the financial gap between grant and private funding, AEPC helped developers identify access to credit with single digit interest rates via the Abu Dhabi Fund for Development (ADFD). Developers would normally have to borrow from commercial banks at much higher interest rates, 14–18 percent.

Table 1. Project Components

Component	Description	CIF Funding	Total Funding
Component 1: Technical Assistance	**Identification of investors:** Call for expression of interest to identify waste to energy (WTE) projects **Market research to identify viable projects:** Evaluating proposals, shortlisting companies, and market research/technical due diligence **Capacity building for Nepalese companies** whose proposals were selected, providing exposure to proven technologies for selected types of waste, site visits and trainings, and potential partnerships with investors, as well as post-construction third-party due diligence of subprojects by AEPC **Support for AEPC to facilitate policy** and create a conducive environment for WTE technologies through technical assistance[16] and leveraging SREP funds.	$1.5 million (actual $1.26 million)	$1.5 million
Component 2: Financing of Investments	**Support the deployment of about 350 large-scale biogas projects** (over 12 m^3 capacity), including large commercial and municipal WTE projects, by August 2021 (80% commercial, 20% municipal) **Support demonstration subprojects by AEPC:** Partial financing of AEPC subprojects to demonstrate foreign biogas technologies and support capacity enhancement	$6.23 million (actual $2.79 million)	$13.1 million
Component 3: Project Management Support	**Provide capacity building and support to AEPC on all aspects of project management and implementation, including monitoring and evaluation (M&E):** Aimed to strengthen AEPC's capacity to review proposals and carry out M&E; support promotion activities; and to enhance private sector (including developers and municipalities) awareness and capacity.	$0.17 million (actual $0.13 million)	$0.17 million
Total		**$7.9 million (actual $4.2 million)**	**$14.8 million**

Figure 3 illustrates the process flow of the grants to commercial and municipal biogas subprojects. The general process included an online application, feasibility study, advance subsidy payment, construction and operation, testing and commissioning, and remaining subsidy payment. Originally, the SREP funds for the development of biogas plants (component 2) were to be provided after the plants were commissioned and operational. However, this process was altered halfway through the project, so CIF funds were disbursed throughout the construction period through milestone-based disbursement, as the original funding structure proved a barrier for developers to manage the cash flow to completing projects on the planned timeline. Still, 10 percent of the total subsidy was retained for one year after testing and commissioning, and was released after the plant operated successfully for one year.

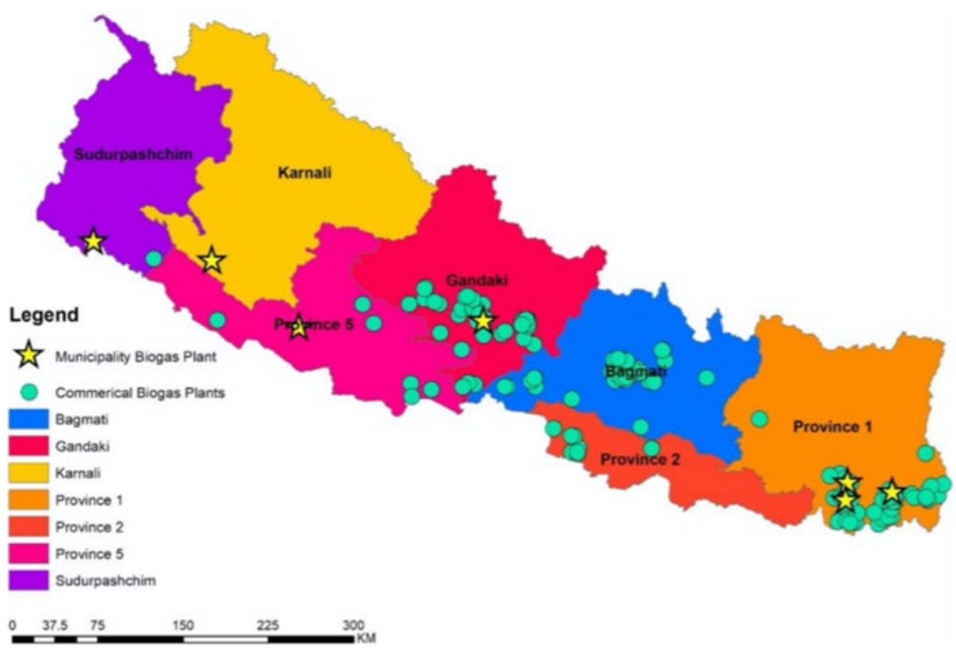
Figure 3. Process Flow of the Commercial and Municipal Subprojects



Source: Project Appraisal Document.

As indicated in Figure 3, biogas plant investment subprojects were selected based on economic and technical feasibility. The projects were located throughout Nepal, though many projects are centralized in certain provinces, namely in Gandaki, Bagmati, and Province 1 (Figure 4).

Figure 4. Locations of Commercial and Municipal Biogas Projects



Source: AEPC (2021). https://srepadmin.srepnepal.org/storage/contents/contents-306f5827-6d43-4a58-88a2-92202f200fe3.pdf

As of August 2021, when the project closed, 195 large-scale biodigesters were installed, ranging in size from 12 to 200 m^3, and 11 very large biogas projects, with capacities around 3,000–4,000 m^3, were near completion. Five of these were municipal plants.[17] Commercial plants were developed by private companies. As noted above, significant delays, due to a great extent to the pandemic, limited how many subprojects could be funded or completed before the project's end.

Development Impact Pathways and Case Study Focus

The main objective of the Extended Biogas Project was to promote market-led approaches to commercially viable large off-grid biogas production from municipal and commercial waste through public-private partnerships. Large biogas plants developed under the project were intended to generate biogas for commercial production of bottled produced natural gas (PNG) and electricity—by selling the gas commercially in cylinders, piping to local households, or converting to electricity via biogas generators.[18] The project also aimed to promote biogas generation from private sector waste and to enhance waste management through technical assistance and financial support for the development of commercially viable business models.

The project's financial and technical interventions have market, economic, social, environmental, and capacity development impacts. The SREP funds, which were channeled through the AEPC to support the large-scale biogas projects, accelerated the development and expansion of the biogas sector in Nepal. These projects provided new local jobs and business opportunities, and they improved Nepal's energy security by boosting domestic energy production and reducing dependence on energy imports.

The project's support for capacity building advanced Nepalese expertise in large-scale biogas technologies, enabled private sector involvement, created business opportunities, and increased the capacity of the local commercial banking sector to assess the risks of biogas projects.

The development of the biogas projects and the biogas market leads to environmental benefits, including reduced GHG emissions; reduced land, air, and water pollutants; and resulting health benefits. It also leads to improvements in energy access and gender equity. Indoor air quality in homes improves due to the substitution of harmful cooking fuels, while gender equity improves from reduced time spent by women in cooking activities due to improved fuel efficiency.

The pathways for realizing these DIs are shown in the impact pathway model in Figure 5. The **dark blue boxes** indicate the DIs quantitatively assessed in the case study: off-grid biogas production; off-grid electricity production from biogas; institutional impacts; reduced energy import bills; energy security; access to reliable energy; reduced cost of waste management; biogas market development; reduction of GHG emissions; business opportunities; and local job creation. The **light blue boxes** indicate DIs qualitatively assessed in this case study, as information for quantification was not available; these DIs are reduction of land, air and water pollutants; health benefits; and local gender benefits.

Figure 5. Impact Pathways for Off-Grid Biogas Development

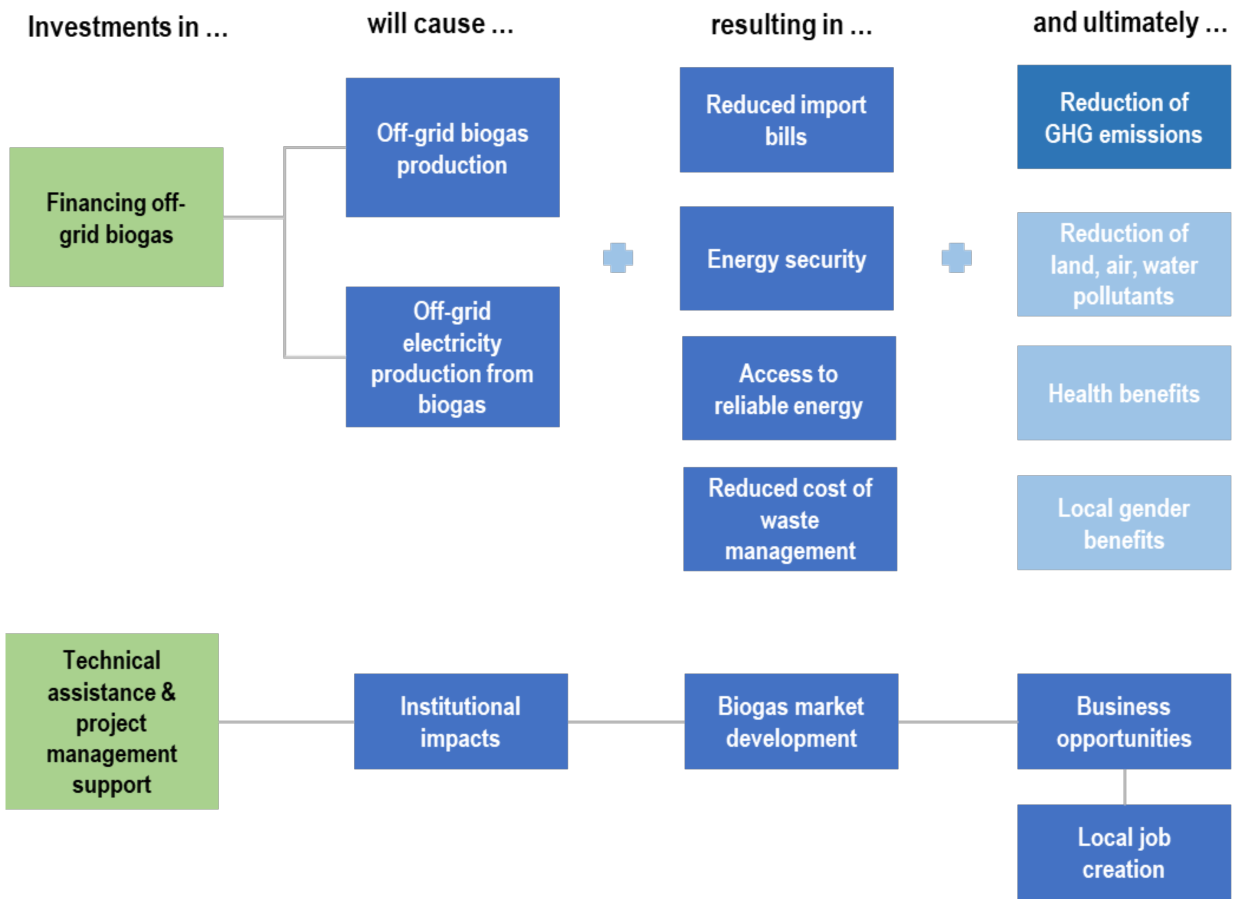


Table 2 shows the extent to which DIs are noted in project documents as potential outcomes and/or are actively tracked and measured.

Table 2. Off-Grid Biogas Development DIs

DI	In Project Documents?	Tracked by Project?
Market DIs		
Biogas market development	YES	NO
Business opportunities	NO	NO
Economic DIs		
Off-grid biogas production	YES	YES
Off-grid electricity generation from biogas	YES	YES
Local job creation	YES	YES
Energy security	YES	NO
Reduced import bills	NO	NO
Reduced cost of waste management	NO	NO
Environmental DIs		
Reduction of GHG emissions	YES	YES
Reduction of land, air, and water pollutants	NO	NO

DI	In Project Documents?	Tracked by Project?
Social DIs		
Access to reliable energy	YES	NO
Health benefits	YES	NO
Local gender benefits	YES	NO
Institutional impacts and capacity development	YES	YES

Key stakeholders include public and private sector actors (Table 3). The key implementing agencies are the AEPC and the Ministry of Finance. AEPC is a governmental body under the Ministry of Energy, Water Resources, and Irrigation (MoEWRI). AEPC was established to promote the use of renewable energy technology to meet energy needs in Nepal, particularly in rural areas. Project developers who received funding and technical support from AEPC delivered large-scale biogas projects. Commercial enterprises and municipalities benefiting from large-scale biogas projects incorporate biogas production in their business models, which can reduce the cost of organic waste management, provide a reliable energy source, and reduce the need for expensive imported fossil fuels. Municipalities across Nepal are also stakeholders in biogas projects, since they are the main responsible entities for land allocation and acquisition related to project development and can partner with private enterprises to generate biogas for commercial heating purposes. Lenders (mostly commercial banks) provide debt financing for biogas project developers. Finally, third-party consultants are involved in feasibility studies, impact assessments, testing, project commissioning, and monitoring.

Table 16. Key Stakeholders and Roles

Stakeholders	Roles
AEPC, Ministry of Finance, GoN	Key implementing agencies
Project developers	Develop large-scale biogas projects, commercial or municipal, with SREP funds and support from AEPC
Municipalities	Project beneficiaries; responsible for allocating land to projects
Lenders (commercial banks)	Provide financing to project developers
Third-party consultants	Assess, commission, and test completed projects; monitoring and evaluation
Commercial enterprises	Project beneficiaries from the biogas projects

Document review and interviews were the main data sources for this case study. The World Bank project documentation described the project's objectives and structure[19] as well as the implementation status and results.[20] The SREP Extended Biogas Project implementation summary reports[21] provided details about the project objectives and components, targets versus achievements, implementation status, monitoring and evaluation activities, environmental and social safeguards, and indicators. The interviewed stakeholders also shared some documents with the evaluation team that helped to inform our assessment of the project's DIs. Four interviews were conducted to capture insights from key stakeholders (Table 4).

Table 17. Interviewed Stakeholders

Organization	Stakeholder Type
AEPC	Key implementing agency for the GoN
Envipower Energy and Fertilizer Pvt. Ltd	Developer, commercial large-scale biogas project
Venture Waste to Energy	Developer, municipal large-scale WTE project
World Bank	Project task team leader

Development Impacts from Off-Grid Biogas Generation

The selection of DIs is based on the project's development objectives, and the indicative and actual results. Based on data availability and the importance of the DIs identified, we categorized four types of impacts: market development, economic, environmental, and social (including the cross-cutting categories of gender-related impacts and capacity building).

The project had four stated development objectives: (i) overall alleviation of energy poverty in Nepal, by modernizing the off-grid, traditional energy sector; (ii) providing gender co-benefits in commercial and municipal-sponsored subprojects where biogas production will benefit women; (iii) greening the growth path for Nepal by reducing GHG emissions from decomposing organic waste; and (iv) mainstreaming sustainable clean energy sources by recycling organic waste for commercial benefit.

According to the AEPC, all those objectives were achieved or exceeded, except for modernizing off-grid electricity. Initially, during the project appraisal phase, there was a dual focus on the production of biogas for sale, and biogas for power production, due to significant power shortages in Nepal. However, the power shortage issue was resolved outside of the project (an unofficial fuel blockade by India was lifted), and therefore it was not further pursued within the scope of the Extended Biogas Project. The development objective indicators also changed to focus on the production of biogas and heat.

Table 5 summarizes key targets for the objectives and results at project completion in August 2021. The project exceeded its (revised) targets for off-grid biogas production and electricity generation. Targets were also exceeded for training provided to companies and for the number of proposals submitted for evaluation. However, targets were not achieved for the number of plants created and operated (just over half of the targeted number), and for municipal plants only one of ten plants were completed. The reasons for underachieving against these targets include significant delays in implementation caused by a 2015 earthquake, instability in World Bank task team leader positions and the COVID pandemic. For the municipal plants, finding available land also proved to be major barrier. The delays impacted financial disbursement as well. The fact that biogas and electricity targets were surpassed is partially attributed to an increased focus on larger biogas plants than originally proposed.

Table 5. Project Results and Targets

Indicator	Result at Completion	Target
Off-grid biogas generated for thermal application from large scale projects (m^3)	17,777,395	16,050,186
Electricity generated for off-grid electrification (GWh)	4.94	4.51
Number of large biogas proposals submitted for investment evaluation – Commercial	640	350
Number of companies trained to evaluate and appraise large biogas subprojects	40	8
Number of off-grid generation plants created and operated by the project – commercial	193	340
Number of off-grid generation plants created and operated by the project – municipalities	1	10
Financial disbursement	$4.18m	$7.90m

Source: Implementation Completion and Results report (March 2022).

Market impacts

The Extended Biogas Project had two types of market impacts: market development and creation of business opportunities. The project advanced the development of the biogas market in Nepal by raising awareness, providing training to relevant stakeholders, and introducing commercially feasible biogas/WTE technologies. In addition, by financing investments in biogas projects, it reduced the risk of large-scale biogas investments and increased the appetite of the private and public sectors to invest in these types of projects. The development of a market for biogas in Nepal also resulted in new business opportunities, as discussed below.

Biogas market development

The project resulted in the development of a large-scale biogas market in Nepal.

Through the technical assistance component (component 1), the project supported the promotion and adoption of new technologies that are commercially mature, particularly: i) continuous-flow stirred tank reactor (CSTR) facilities, where agricultural/industrial residues are used to produce biogas that can be burned to generate heat/electricity, as well as digestate that can be used for organic fertilizer; and ii) MSW management, with the outputs used as a feedstock for municipal waste to energy (WTE) subprojects.

The project also included six trainings/orientation events and ten promotional events. In particular, the project included the following activities and events to raise awareness and promote involvement of stakeholders in the biogas sector:

- **Training on designing and planning of CSTR biogas plants**, for construction companies, large biogas construction companies, potential developers and Project Implementing Unit (PIU) members from AEPC and SREP;
- **Dissemination of information to local leaders on the importance of waste management via WTE systems and technology options available**, for mayors of municipalities, ongoing and potential developers, and implementation partners and construction companies;

- **Dissemination of information to implementation partners about the project cycle of large biogas plants and related issues**, for consulting firms, construction companies, and supporting agencies;
- **10 promotional events across Nepal to inform local stakeholders and potential developers** about WTE technology and the technical/financial support offered by AEPC and SREP for subproject development; and
- **Exposure visit to a WTE project in Delhi, India**, which supplies gas through a grid-based distribution system, coordinated and promoted for developers and municipal staff.

Within the scope of the technical assistance (component 1), at first, project developers required support from AEPC to convince banks to lend, as banks were not familiar with biogas projects. Since the program, the capacity of the commercial banking sector has increased, in terms of assessing and understanding the risks of biogas-related business plans. Project developers noted that the experience gained by both parties and demonstrated success of the first projects has facilitated the lending process for subsequent projects.[22]

The financing component (component 2) provided SREP funding that was channeled through AEPC, which in turn helped leverage co-financing to further expand and develop the biogas sector in Nepal. The project focused on enabling private sector involvement by developing private sector-led models to expand the deployment of large-scale biogas technologies. The project provided 20 percent grant funding to projects, in addition to 20 percent provided by the AEPC, and 60 percent by the project developer, the latter typically sourced through the developer's own funds or commercial finance (loans). On the basis of disbursement of $2.79 million for this component at project closing and estimated match funding of $2.79 million from the AEPC, an additional $8.37 million of private funding was brought in. These values may have increased after the project closed, as a number of projects were still in construction/completed and awaiting verification to receive funds.

Business opportunities

The Extended Biogas Project resulted in several types of new business opportunities in Nepal:

- **Multiple end-uses for biogas.** Commercial biogas plants are selling biogas for various applications (see Table 5 for volumes), including thermal (industrial heat) applications, as a replacement for LPG in restaurants and hotels, and electricity generation. The project has led to the substitution of 0.6 million LPG cylinders per year that would otherwise be imported from India.[23] In particular, each developer selling bottled biogas is catering to the needs of at least 50 customers, including restaurants, hotels, and other industry. In addition to serving the needs of the end users, this is a financially attractive business opportunity for the biogas developers/sellers. When the project began in 2015, there was a significant shortage in the supply of fossil fuels, and in Nepal, prices surged to about $100 per gas cylinder. Biogas, meanwhile, was selling for about $15 per cylinder. Thus, biogas projects were financially attractive, with an estimated internal rate of return (IRR) of 49 percent. An interviewed developer who is active in this space stated that it was more feasible to sell compressed natural gas (CNG) produced from biogas in gas cylinders than to generate electricity from the biogas.

- **Organic fertilizers as a byproduct of biogas:** The digestates that are a byproduct of biogas production can be sold to local farmers as high-quality organic fertilizers, at a cost that is competitive with chemical fertilizers. In addition to providing a potential business opportunity for the biogas seller, organic fertilizer can improve soil quality and crop yield for the farmers, in turn enhancing farmer incomes. To date, 68,000 Mt of organic fertilizers have been produced annually [24] and distributed for free to local farmers,[25] or else sold, but at a lower price than was originally expected. This issue is further discussed in the drivers and barriers section.
- **Small biomass as a feedstock for biogas production:** Finally, the project has created business opportunities for small biomass producers (e.g., farmers) who supply biomass to the new biogas plants. This is discussed in further detail below.

Economic impacts

As summarized in Table 5, the project exceeded its targets for off-grid biogas production and off-grid electricity generation from biogas. These accomplishments, and the broader market development impacts described in the previous section, contributed to the achievement of economic development impacts. These include local job creation, improved energy security, reduced energy imports, reduced import bills, and reduced costs of waste management.

Local job creation

A newly constructed biogas plant is estimated to create permanent employment for around 20 employees in MSW WTE plants and 50 employees in commercial biogas plants.[26] During the construction phase, biogas projects can temporarily employ up to 200 people.[27] Evidence from interviews broadly corroborated these estimates, with a very large plant estimated to directly employ around 25 staff (about 10 skilled and 15 unskilled jobs). Based on the number of plants constructed, the program is estimated to have directly generated about 1,000–1,200 jobs at biogas facilities across Nepal.

The projects also created temporary jobs in construction and indirect job opportunities through the supply chain (e.g., in waste collection and sorting). However, workers with high-level technical skills still need to be brought over from India.

Energy security

A key reason for the GoN to prioritize biogas project development is to improve the country's energy security. By replacing LPG fuel with biogas at industrial scale for heating applications, an estimated 600,000 LPG cylinders have been replaced by biogas produced from SREP-supported subprojects. This translates to over $5 million worth of import substitution.[28]

The project has also improved energy security for project beneficiaries (mainly businesses and commercial establishments) who invested in biogas technologies to increase their on-site energy security. Greater energy security in turn improves their productivity and indirectly supports employment. The number of businesses and community services benefiting from improved access to electricity and fuels as a result of the SREP-funded subprojects was estimated to be 350, including 340 commercial businesses and 10 municipal services.[29]

Reduced import bills

Around 88,000 tons of organic fertilizer are produced per year as a result of the project. The production of organic fertilizer (digestate from the biogas plants) can replace chemical fertilizers leading to reduced import bills in Nepal. Reductions in imports help to make the country less vulnerable to global fluctuations in fertilizer prices and energy prices. In 2021 Nepal imported around 400,000 tons of chemical or mineral fertilizers, valued at about US$200 million.[30] If every ton of organic fertilizer replaced a ton of imported fertilizers, the 68,000 tons produced could reduce import needs by about US$34 million per year. However, there have been difficulties in getting farmers to accept and use the new organic fertilizers.

Reduced cost of waste management

The project has reduced the cost of waste management for farmers by turning their waste into a feedstock for the biogas plants, and in fact, has created a new revenue stream. A survey conducted on a cow farm assessed the impact of the project on the waste management costs incurred by farm owners. Before the project, the farm owner had to manage the cow dung in the backyard of the farm and was only able to sell small amounts to the markets at a low price (~500 NPR/$4 per tractor). However, after the farm owner established a long-term contract with a large-scale biogas plant, he was able to supply waste (animal dung) on a daily basis, with a fixed monthly income. The estimated additional income to the cow farmer was about 23,000 NPR/$188 per month.[31] Similar results across other projects would not only result in significant reductions in waste management costs, but would also generate a source of revenue for farm owners/biomass suppliers (and potentially, municipalities).

Environmental impacts

The Extended Biogas Project had several environmental benefits, including reduced GHG emissions and reduced land, air, and water pollutants.

Reduction of GHG emissions

By replacing fossil fuels used in energy generation (e.g., diesel in diesel generators/furnaces and LPG as cooking fuel) with biogas for thermal energy and electricity generation, the SREP subprojects have avoided an estimated 90,754 tCO_2e annually, translating to 1,815 $ktCO_2e$ over a 20-year lifetime of the biogas plants.[32] Those anticipated emissions reductions have the potential to facilitate the development of carbon financing programs in Nepal. Accordingly, a Program of Activities (PoA)[33] under the Kyoto Protocol has been designed by bundling the subprojects implemented under the SREP, as well as future projects, to mobilize carbon financing by selling certified emissions reductions on global markets.[34]

Reduction of land, air, and water pollution

Electricity generation using diesel generators contributes to substantial amounts of NOx, SOx and PM emissions,[35] with negative impacts on the environment and health for the neighboring communities. Biogas represents a cleaner alternative with associated environmental benefits.

The wastes and biomass residues (e.g., crop residues and animal manure) that are currently being used in the large-scale biogas/WTE plants would have likely been improperly managed either by open dumping in forests or by disposing of them in waterways, causing land and water pollution. Wastes used in the biogas plants will result in reducing landfill waste on site by at least 50–60 percent, and some estimate by as much as 90 percent in regions without functioning waste collection systems.[36] However, the actual performance was not tracked by the project.

Social impacts

The Extended Biogas Project's social development impacts include access to reliable energy, health benefits, and specific benefits for women.

Access to reliable energy

As of 2021, the project has improved energy access for 275 businesses, with a target to improve energy access to 350 businesses, due to weaknesses in monitoring it is unclear if the program reached its target at close.[37] Improved energy access for households was not monitored, according to AEPC, as with the restructuring of the program away from electricity, the projects focused on commercial customers rather than households. Biogas produced by the plants has advantages for reliability of access, as it is based on renewable domestic sources, rather than international imports and markets. It is also more affordable than LPG[38] and thus can make heating/electricity more affordable. Energy cost savings for consumers were estimated to range from 25 to 30 percent by switching from fossil fuels to bio-CNG.[39]

This increase in access to reliable (and lower-cost) energy is hoped to have further positive impacts on the community, including reduced drudgery (e.g., gathering firewood), freeing up time for other activities, and the ability to afford lighting for children's education. However, these impacts were not monitored.

Health benefits

Harmful cooking fuels that are used in rural areas for long durations each day have negative impacts on indoor air quality in homes. These adverse health impacts especially affect women, who typically have household responsibilities including cooking, and therefore face high exposure to smoke. This exposure may result in acute respiratory diseases, eye infections, and headaches. Although data to quantify health benefits were not available, it is reasonable to assume that the Extended Biogas Project reduced local air pollutants (indoor and ambient), and in turn led to positive health impacts.

Gender benefits

Gender benefits have been realized from the substitution of harmful cooking fuels through community-sponsored projects. The project saved each family about three hours per day by reducing time spent collecting fuel wood, cooking, and cleaning.[40] As noted above, it also reduced exposure of households (especially women) to the negative health impacts of harmful cooking fuels.

Another benefit arising from the Extended Biogas Project was increased employment opportunities for women in connection with waste sorting activities in plant operations. Moreover, one of the municipal WTE projects (Venture) distributed free adapter kits to convert three-wheelers to run on CNG, and priority of distribution was given to women and families with single and/or low incomes. At the time of this assessment, the developer had distributed two kits and claimed commitments from suppliers and sponsors for a further 45 kits. However, it is worth mentioning that the AEPC and project developers did not closely monitor the project's gender impacts.

Drivers and Barriers

Drivers

Several drivers supported the success of the Extended Biogas Project and the development of the large-scale biogas market in Nepal:

Public-private partnership

The public-private partnership approach for funding was a key driver of success. In particular, the combination of the SREP financing and the GoN's willingness to provide matching funds was instrumental in attracting project developers and private finance which successfully promoted and expanded the large biogas sector in Nepal.[41] Interviews with developers highlight that following successful first plant implementation the developers are each privately developing further plants.

Technical assistance

Technical assistance was necessary to complement the funding component**.** In addition to the financial support provided through component 2 of the project, the technical assistance (component 1) was very helpful in supporting the AEPC, project developers, and other stakeholders involved in the project to strengthen their capacity in large-scale biogas. However, as mentioned previously, the sector is still lagging on technical expertise on the operation and maintenance of large biogas plants, not least due to high staff turnover in the sector.

Financial competitiveness of biogas

The financial attractiveness of biogas supported the project's efforts to develop this sector**.** The financial competitiveness of biogas produced in Nepal relative to imported fossil fuels was very high, with an estimated IRR of 49 percent. This was a key driver for project developers to pursue biogas developments. Most of the interviewed project developers are already in the process of developing additional large-scale biogas/WTE projects.

Barriers

Although the Extended Biogas Project was highly successful on several dimensions, there were barriers that hindered or delayed the development of the subprojects and the resulting DIs.

COVID-19 pandemic

As noted above, the COVID-19 pandemic reduced the mobilization and utilization of Project Implementing Unit (PIU) resources[42] and slowed down technical assistance, project identification, preparation, and construction. Project activities continued, but at a reduced scale and speed. The pandemic also made it difficult for independent verifiers to travel to project sites.

Lack of demand for organic fertilizer

Lack of demand for organic fertilizer has been a challenge. Local farmers believe that chemical fertilizers increase yields more, so they have been reluctant to use the digestate instead. Evidence suggests that while chemical fertilizers may raise yields by more in the short term, they also deplete soil fertility, while organic fertilizers from biogas plants give longer-lasting boosts to yields; combined use of both may give the best effects.[43] With low demand, organic fertilizer has had to be sold at a lower price than anticipated by project developers in their business plans (15–18 rupees/kg instead of 25), and only in some geographic areas. Developers were anticipating significant revenue from selling organic fertilizer, but the lack of demand has reduced profitability relative to their expectations.

Lack of maintenance expertise

Lack of maintenance expertise reduces local employment opportunities and entails higher costs. The large-scale biogas industry requires routine maintenance, which could provide local employment opportunities, except that most maintenance requires bringing over maintenance experts from India due to lack of technical expertise by Nepalis. Bringing in Indian maintenance experts comes at a high cost, especially if the maintenance was unplanned and requires shutting down the plant. One operator of a large plant estimated that each day of closure costs around $600, which is a large loss for these types of projects. The AEPC is requesting support from funding agencies to build the capacity of Nepali specialists.

Financing barriers

Financing barriers constrain market development**.** Although there is interest among developers to invest in biogas technology, the requirement of financing 60 percent of the project using private financing, which would cost around $2 million, poses a significant challenge for many developers. Prior to the project, financial institutions were reluctant to provide sufficient debt financing to these type of biogas projects because of their lack of understanding of the technology and the risks involved. However, as the success of the SREP subprojects has become more prevalent, project developers report that banks have become more open to providing financing for these types of projects.[44]

Despite the successes achieved during the project, barriers remain. Currently, interest rates are as high as 14–18 percent, which is a high hurdle for project developers to make a positive business case. Another issue raised by project developers is that funding was provided against assets only, and not for land acquisition, which was an obstacle in some cases as land is scarce and often expensive.

Lack of adequate infrastructure

Lack of adequate infrastructure also constrains market development. The bio-CNG produced from biogas plants must be bottled before being sold to the market, since there is no available pipeline infrastructure to inject and transport gas. Expanding the CNG cylinder capacity in Nepal has incurred additional costs and reduced profitability. In contrast, other countries like India have more developed infrastructure and larger cylinder capacity.

Establish a reliable input supply

Operational issues for biogas include the reliability of biomass supply. This is because project developers most often do not have legal contracts with suppliers, since biomass is sourced from small producers who do not typically enter into written agreements (illiteracy is an issue).

Land acquisition issues

Land acquisition issues were the reason behind developing fewer municipal WTE projects than planned (one completed versus 10 targeted). The reason for that is the high value of land in Nepal, especially in large cities, and therefore WTE projects had to compete with other types of projects to secure sites, which had to be negotiated with mayors in cities and municipalities.[45]

CIF and MDB Contributions to DIs

CIF's contribution through SREP funds was an important contributor to the success of the Extended Biogas Project and to mitigating some of the project barriers. In the absence of the project, the energy needs satisfied by biogas would have either gone unmet, or been met with imported fuels or traditional biomass. Project beneficiaries such as commercial enterprises, hotels, and industries would have incurred considerable costs and time on non-core activities that include procuring fuels (e.g., diesel) and backup generators to address electricity and energy shortages in Nepal.

CIF's contribution through technical assistance (component 1) resulted in building capacity at AEPC and other stakeholders in the biogas sector, including project developers and the banking sector. This support, particularly the strengthening of capacity at AEPC, was particularly valued.

CIF's contribution to financing investments (component 2) was instrumental in catalyzing and leveraging further investments in the large-scale biogas sector in Nepal. Originally, the SREP grant was to be provided at the end of the subproject completion; however, due to issues with cash flow for developers and resulting delays for larger projects, the CIF funding was disbursed throughout the construction phase to alleviate this issue.

Future Opportunities: Lessons Learned on Energy Transition for CIF and Other Climate Funders

Development opportunities and barriers

Beyond the technical assistance component of the project, which focused on the pre-operation phase of the biogas plants, there is still significant room to enhance technical capacity within the biogas sector in Nepal. This is due to the lack of technical proficiency to operate and maintain large-scale biogas plants, where most of the maintenance expertise comes from India at a high cost to the project developers. In that sense, future programs could also provide support in setting up maintenance companies in Nepal.

Since the project was mostly targeting the commercial biogas sector in Nepal, several DIs were not closely monitored or were overlooked. For instance, gender co-benefits arising from the project were not closely monitored and evaluated. Also, the number of household beneficiaries was roughly estimated by AEPC and project developers but was not fully assessed. Furthermore, positive health impacts on households were qualitatively evaluated, but not quantified, even though this is a potentially major outcome of the project. Future efforts could provide the tools and technical knowledge for project developers and the implementing agency (AEPC) to assess key project Dis, which could in turn help strengthen the case for biogas development in Nepal.

Lessons learned for biogas projects

Emphasize capacity building

Capacity building is key for financial institutions involved in the project. The process of acquiring loans from commercial banks to finance projects can be challenging. AECP's support to banks to help them understand the projects is valuable to facilitate financing of biogas projects. Further support of this type in Nepal would still be beneficial to continue to support the pipeline of projects. If the project approach were replicated in other countries with a similar lack of familiarity with large biogas projects then this capacity building for financial institutions should be an important element of the program.

Support the business case

The business case for organic fertilizers (as a byproduct of biogas production) needs to be supported. Raising the awareness of local farmers about the benefits of organic fertilizers over chemical fertilizers is still needed. Most interviewed stakeholders are currently distributing their digestate for free to farmers, which does not support the business case for project developers.

Land negotiations for municipal projects

Land negotiations for municipal projects are essential to move forward with the project. So far, only one municipal project has been fully implemented under the Extended Biogas Project. This was due in part to challenges with land acquisition. Developers usually have concessional agreements with municipalities for 20 years on project land. However, political issues are common, because of the high value of land and competition of large-scale biogas projects with other types of projects, including waste management projects, which are higher priorities to the mayors and municipal officials. This made land acquisition for municipal projects more complex than expected, unlike commercial projects where project developers acquired land themselves.

Interim milestones for fund disbursement are needed for large projects

For small projects, it is not necessary to have milestone-based disbursement, but for larger projects (costing $200,000–300,000), not having the funds created cash flow issues for developers, which led to delays. Waiting until the end of the project to provide funding was a barrier that can be addressed by providing disbursements throughout the construction process instead of post-implementation.

Potential for replication and scaling

AEPC has approached the International Renewable Energy Agency (IRENA) and ADFD, which approved $10 million of soft loans to the project. Since many subprojects are in the pipeline, they were expecting to use ADFD funds for these projects, however, this has been delayed due to the COVID situation.

AEPC also developed a Green Climate Fund (GCF) concept note for follow-up projects[46] and is working on a detailed GCF funding proposal. The project also received strong interest from developers, and chances appear high that there will be a follow-up program for similar projects. Most of the interviewed project developers are willing and have taken the steps to invest again in similar projects.

The following points are potential measures to expedite project implementation:

- Continue working with local banks, developers, construction companies, and service providers to develop their capacity and confidence in biogas and WTE technologies, project financing, and operation and maintenance.
- Monitor subproject progress including construction activities to facilitate and address bottlenecks and issues—such as contractual issues, coordination with local authorities/communities, facilitation of necessary construction related approvals, etc.

- Work closely with the Nepal Bureau of Standards and Metrology to develop standards for project components, layout, and quality of gas and digestate organic fertilizer. This will strengthen safety regulations for gas generation and handling while supporting an enabling environment for further scale-up of the technology. It will also support the marketing and sales of the digestate as organic fertilizer to local farms and other markets outside Nepal.

Improving the programmatic approach to climate finance

The Extended Biogas Project was able to achieve several DIs in the areas of market development, economic impacts, gender benefits, environmental benefits, and social impacts. However, it is still important to address country-specific challenges such as lack of domestic maintenance expertise and lack of necessary infrastructure to maximize the realization of DIs through project implementation. It is also important to ensure that project developers and implementing agencies can assess the DIs realized by the project.

Endnotes

[1] See World Bank country overview: https://www.worldbank.org/en/country/nepal/overview#1.
[2] See World Bank data for gross national income (GNI) per capita, Atlas method, in current US$: https://data.worldbank.org/indicator/NY.GNP.PCAP.CD?locations=NP. This puts Nepal on the low end of the lower-middle-income countries category (see https://blogs.worldbank.org/opendata/new-world-bank-country-classifications-income-level-2022-2023).
[3] UNDP (2022). Human Development Report 2021/2022. New York: United Nations Development Programme. https://hdr.undp.org/content/human-development-report-2021-22.
[4] See World Bank data for total population: https://data.worldbank.org/indicator/SP.POP.TOTL?locations=NP and share of rural population: https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS?locations=NP.
[5] IEA (n.d.). Nepal. Available at: https://www.iea.org/countries/nepal
[6] Poudyal, R. et al. (2019). Mitigating the current energy crisis in Nepal with renewable energy sources. Available at: https://doi.org/10.1016/j.rser.2019.109388.
Disruptions caused by the COVID-19 pandemic led to further negative impacts on Nepal's development by slowing down the rate of economic growth (GDP 1.8% in 2021 compared with 2.1% in 2020), which also created a surge in debt levels and an increase in poverty rates.
[7] IEA (2017). Renewable energy subsidy policy of Nepal. Available at: https://www.iea.org/policies/6228-renewable-energy-subsidy-policy-of-nepal
[8] IEA (2017). Rural energy policy in Nepal. Available at: https://www.iea.org/policies/6229-rural-energy-policy-of-nepal
[9] IEA (n.d.). Nepal. Available at: https://www.iea.org/countries/nepal
[10] IEA (n.d.). Nepal. Available at: https://www.iea.org/countries/nepal
[11] Central Bureau of Statistics (2021) Waste management baseline survey of Nepal 2020.; Mandal, C.K. (2021). Only half of municipal waste gets collected, far less recycled. Available at: https://kathmandupost.com/climate-environment/2021/05/11/only-half-of-municipal-waste-gets-collected-far-less-recycled
[12] Government of Nepal (2021). Nepal's long-term strategy for Net-Zero emissions. Available at: https://unfccc.int/sites/default/files/resource/NepalLTLEDS.pdf
[13] Around 50–60% of MSW in Nepal is composed of organic wastes.
[14] The AEPC also implemented the NRREP-funded large biogas program. The National Rural and Renewable Energy Program (NRREP) was a five-year initiative (2012–2017) that promoted renewable energy technologies through the AEPC. It was supported by bilateral grants from Denmark, Netherlands, Norway, Germany, United Kingdom and the UNDP, with a total budget of US$170.1 million.
[15] See World Bank (2022). Nepal – SREP – Supported Extended Biogas Project: Implementation Completion and Results Report. Washington, DC. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/639921648216491573/nepal-srep-supported-extended-biogas-project.
The report notes (p. 30, § 10): "AEPC received and screened 640 applications for support for thermal and electricity generation sub-projects while only 194 sub-projects could be completed by Project closure. The frequent turnover of TTLs, a 20-month

extension, and three restructurings to reassess the Project's designs for such a small operation have increased supervision costs and suggest inefficiency. Lastly, the Project had to cope with the severe disruptions to all economic activity caused by COVID-19. Nepal was particularly hard hit by COVID-19, as was the case in most countries, and there was a period of at least 12 months when normal activities were put on hold. To illustrate, while 122 sub-projects were completed in 2017 and 2018, only 53 sub-projects were completed in 2019 and 2020."

[16] The technical assistance included capacity building within the AEPC and other stakeholders, technology acquisition, feasibility study/detailed feasibility study, awareness creation, support to academic and research institutions, and hiring an independent consultant for annual evaluation of the program.

[17] Interview with AEPC representatives.

[18] https://srepadmin.srepnepal.org/storage/contents/contents-306f5827-6d43-4a58-88a2-92202f200fe3.pdf

[19] World Bank (2014). Project appraisal document on a proposed grant from the scaling-up renewable energy Program in low income countries (SREP) of the strategic climate fund (SCF) in the amount of US$7.9 million to Nepal for a SREP-supported extended biogas project. Available at: https://pubdocs.worldbank.org/en/598271531555668011/1900-XSRENP023A-Nepal-Project-Document.pdf

[20] World Bank (n.d.). Nepal: SREP- Extended Biogas Project (TF16552) Implementation Review and Support (September 21 to 25, 2020) Aide Memoire. Available at: https://documents1.worldbank.org/curated/en/455991604993617282/pdf/Nepal-SREP-Extended-Biogas-Project-Implementation-Review-and-Support-Mission-September-21-to-25-2020.pdf; World Bank (2020). SREP – supported extended biogas project (P131592) implementation status and results report. Available at: https://documents1.worldbank.org/curated/en/141711604962382680/pdf/Disclosable-Version-of-the-ISR-SREP-Supported-Extended-Biogas-Project-P131592-Sequence-No-11.pdf

[21] Available at: https://srepadmin.srepnepal.org/storage/contents/contents-306f5827-6d43-4a58-88a2-92202f200fe3.pdf and https://srepadmin.srepnepal.org/storage/contents/contents-2f998848-de34-4c05-b9c9-f288cae340ed.pdf.

[22] Interviews with project developers and AEPC.

[23] World Bank (2022). Implementation completion and results report on a grant from the scaling-up renewable energy program in low income countries in the amount US$7.9 million to Nepal for the SREP-supported extended biogas project.

[24] World Bank (2022). Implementation completion and results report on a grant from the scaling-up renewable energy program in low income countries in the amount US$7.9 million to Nepal for the SREP-supported extended biogas project.

[25] Interview with 3 large-scale project developers (2 commercial and 1 municipal).

[26] Prakash Aryal, (2018). A Thesis Submitted to Department of Economics, Patan Multiple Campus Faculty of Humanities and Social Sciences, Tribhuvan University, Nepal In partial fulfillment of the requirements for the Degree of Master of Arts in Economics.

[27] Ibid.

[28] Based on a value of 1100 Nepalese Rupee per LPG cylinder and an exchange rate of 130 rupees to 1 US dollar.

[29] World Bank (2020). Disclosable Restructuring Paper - SREP-Supported Extended Biogas Project - P131592 (English). Available at: https://documents.worldbank.org/en/publication/documents-reports/documentdetail/620271586250322286/disclosable-restructuring-paper-srep-supported-extended-biogas-project-p131592

[30] Statistics from UN Comtrade, aggregate of HS codes 3102, 3103, 3104, 3105

[31] Prakash Aryal, (2018), a Masters Thesis Submitted to Department of Economics, Patan Multiple Campus Faculty of Humanities and Social Sciences, Tribhuvan University, Nepal

[32] The calculation was based on 793 tCO_2e of GHG emission savings per GWh. The methodology and assumptions are available in Annex 7 of the original project appraisal document available here: http://pubdocs.worldbank.org/en/598271531555668011/1900- XSRENP023A-Nepal-Project-Document.pdf

[33] Clean Development Mechanism (CDM)

[34] https://srepadmin.srepnepal.org/storage/contents/contents-306f5827-6d43-4a58-88a2-92202f200fe3.pdf

[35] See p33-35 of RERIC (2018) Emissions of air pollutants and greenhouse Gases in Nepal: an integrated inventory

[36] Prakash Aryal, (2018), A Thesis Submitted to Department of Economics, Patan Multiple Campus Faculty of Humanities and Social Sciences, Tribhuvan University, Nepal In partial fulfillment of the requirements for the Degree of Master of Arts in Economics

[37] https://srepadmin.srepnepal.org/storage/contents/contents-306f5827-6d43-4a58-88a2-92202f200fe3.pdf

[38] https://www.climateinvestmentfunds.org/CIF10/nepal/bhairahawa

[39] Based on interview with project developer.

[40] Estimated on basis of interviews.

[41] https://srepadmin.srepnepal.org/storage/contents/contents-306f5827-6d43-4a58-88a2-92202f200fe3.pdf

[42] The PIU faced a staffing and resource crunch earlier in the project, partially due to the closure of the Nepal Rural and Renewable Energy Program (NRREP). As of July 2020 the PIU was fully staffed.
See the World Bank's Implementation Completion and Results Report for more details on delays.

[43] Tang, J.; Yin, J.; Davy, A.J.; Pan, F.; Han, X.; Huang, S.; Wu, D. Biogas Slurry as an Alternative to Chemical Fertilizer: Changes in Soil Properties and Microbial Communities of Fluvo-Aquic Soil in the North China Plain. Sustainability 2022, 14, 15099. https://doi.org/ 10.3390/su142215099

[44] Based on interviews with project developers and AEPC.

[45] Interview with AEPC representatives.

[46] See https://www.greenclimate.fund/document/enhancing-energy-access-generating-energy-waste-mitigating-climate-change.

11. Niger Light-Touch Case Study: Mainstreaming Climate Resilience of Populations and Agricultural Production Systems

Project Details	Funding
Project Names: Community Action Project for Climate Resilience (CAPCR-1) Niger Community Action Project for Climate Resilience (CAPCR-2) **Country:** Niger **CIF Program Area:** Pilot Program for Climate Resilience (PPCR) **Bank approval:** January 2012 (CAPCR-1); April 2019 (CAPCR-2) **Effective since:** May 2012 (CAPCR-1); September 2019 (CAPCR-2) **Actual closing:** May 2021 (CAPCR-1 and CAPCR-2) **MDBs:** World Bank	**Total Value:** Total US$77.6 million; includes US$63 million (CAPCR-1); US$14.6 million (CAPCR-2) **CIF:** US$72.6 million **World Bank:** US$5.0 million **Instrument type:** Grant (US$35 million), loan (US$37.6 million) **Sector:** Public *Note: While the total planned value of the two projects was US$77.6 million, the World Bank Implementation Completion Report (ICR) indicates that actual disbursements were US$74.7 million.*

Key Highlights

- The Community Action for Climate Resilience Project (CAPCR) projects in Niger sought to improve the resilience of the populations and agricultural production systems to climate change and variability in 38 targeted communes.
- The projects focused on mainstreaming climate resilience coordination between the national and local levels, with the centerpiece establishment of "Maisons du Paysan" (farmers' houses) in targeted communes to serve as institutional platforms to enable scaling up of interventions in rural areas to improve adaptive capacities of populations and agricultural systems.
- This case study focuses on two CIF Pilot Program for Climate Resilience (PPCR) projects in Niger with a total CIF investment of US$72.6 million.

Topline Findings on Development Impacts

- **Increased agricultural productivity:** The combination of enhanced agricultural inputs (e.g., seed, fertilizer, fodder, equipment) and extension services (e.g., training, equipment repair services, technical assistance, microfinance) increased crop yields by an average of 59 percent annually and enhanced the resilience of agro-silvopastoral production systems in the project areas.
- **Benefits to local stakeholders:** Nearly 500,000 rural producers and poor households in the targeted 38 communes were project beneficiaries (resulting in direct benefits experienced by 2.415 million people, including 1.155 million women), with high corresponding rates of sustainable land and water management practices.

- **Access to essential services:** Community engagement and development of climate resilience capacity was also advanced in target populations and among local institutions, increasing access to a range of agricultural extension and social protection services.
- Measurement and reporting can be improved by using metrics that better reflect DIs of the projects, including impacts on women empowerment, and food security and changes in livelihoods experienced by households.
- An analysis by the CAPCR project team of the development impacts of an innovative project approach—the use of a coaching system paired with results-based management to support effective operationalization of the Maisons du Paysan—provides valuable insights.

Climate Investment Context and Overview

Niger remains one of the poorest countries in Sub-Saharan Africa, with some of the highest malnutrition and mortality rates in the world. Of the roughly 24.9 million people living in Niger in 2022, more than 4.4 million (17 percent) experienced periods of food insecurity, and 6.8 million (27 percent) were chronically food-insecure.[1] Around 84 percent of the population live in rural areas and depend on natural resources, which makes them highly vulnerable to climate change and variability.[2] Niger is hot year-round and has highly variable rainfall, with prolonged and frequent droughts.

Natural resources degradation, population growth, and climate change pose serious challenges to medium- and long-term food security. Poor households, in particular female-headed households, are more vulnerable to climate shocks and seasonal variations in agricultural production, which has often resorted to unconstructive solutions such as the premature sale of seeds and livestock.[3] The links between soil degradation and climate change represent a particular concern, as this requires urgent changes in land management technologies and practices.

In 2010, the Government of Niger (GoN) developed its Strategic Program for Climate Resilience (SPCR) with the goal to increase food security in Niger by improving resilience of populations and production systems to climate change. The plan encompassed four complementary investment projects, including the Community Action Project for Climate Resilience (CAPCR). The GoN recognized the need to improve management of natural resources and was committed to promoting a more holistic approach, particularly in rural communities. Over the past several decades, national institutions have been created to reduce Niger's vulnerability to climate change, such as the Nigeriens Nourish Nigeriens Initiative (3NI), which sought to address chronic shortages of food products by introducing modern farming techniques and creating better access to production value chains. The 3NI sought to empower local governments in development planning and management through decentralized support and mobilization of rural women and youth to anchor initiatives in local communities. Decentralization had been a cornerstone of Niger's development strategy since the 1990s, with the adoption of several legal texts and policies to give the 266 communes, of which 213 are rural, more authority given their relative advantages in terms of the knowledge of local climate-related constraints and appropriate solutions. This included mandates for local development planning, natural resources management, and implementation of social services.[4]

The CAPCR aimed to improve the resilience of the populations and of production systems to climate change and variability in targeted communes. Food security was identified as the "long-term transformative impact" of the project.[5] Table 1 details the three components of the US$63 million project, which was approved in 2012.

Table 1. Components of the Community Action Project for Climate Resilience (CAPCR)

Component	Description
Component 1	**Mainstreaming climate resilience into development strategies at national and local levels** by (a) making the social and economic development policies in the health, water, and road infrastructure sectors more responsive to climate change and (b) defining and implementing a comprehensive communication strategy and a system of effective knowledge management.
Component 2	**Integrating climate resilience practices into agro-silvopastoral systems and local populations' social protection measures** by (a) scaling up sustainable land and water management (SLWM) practices to reduce climate change impacts through capacity-building activities in the areas of agriculture, agro-forestry, agro-pastoralism, and pastoralism, and (b) providing matching grants to targeted communes to finance activities to improve agricultural productivity, sustainable management of forest resources, and productivity of grazing areas, including the development of Maisons du Paysan. In addition, integrate innovative measures for protecting the most poor and vulnerable households by (a) establishing a system of flexible social protection actions to be integrated into local planning processes and (b) providing matching grants to targeted communes to finance social protection actions such as protection and rehabilitation of socioeconomic community facilities.
Component 3	**Ensuring coordination of all the activities of the project, including monitoring and evaluation activities, and SPCR overall strategic coordination including ensuring strategic coordination** to the SPCR and knowledge sharing concerning the project's and SPCR's approach, results, challenges, and impacts at the national level with key stakeholders and at the international level with other countries participating in the PPCR.

A second project, the Niger Community Action Project for Climate Resilience (CAPCR-2), was approved in 2018, a $14.6 million investment to scale up activities and consolidate outcomes of the CAPCR, as well as strengthen the national stakeholders' platform for climate resilience and coordination with other national initiatives and plans.[6] The components were revised in 2019 as part of this additional investment. Existing activities were scaled up with the additional financing made available, and new subcomponents were added to components 1 and 2.

The additional funds for the Niger Community Action Project for Climate Resilience were intended to allow the CAPCR project to scale up and consolidate its well-performing local and national level activities, as well as ensure the longer-term sustainability of the achievements of the CAPCR and the Niger SPCR. The main focus of the additional financing was supporting the continued establishment and operationalization of integrated services platforms on commune level, referred to as "Maisons du Paysan" (MPs), or "Farmers' Houses." These MPs are physical building facilities that can be used to store agricultural inputs (e.g., seeds, fertilizer, equipment) and outputs (e.g., surplus fodder), as well as a location to support integrated technical assistance, social services, and meeting space.

The MPs were designed to reach many inhabitants in a rural commune, allowing the project to scale to provide direct services to a large number of beneficiaries and to sustain this community engagement over time. The services and benefits they delivered included:

- Communal storage of agricultural inputs and outputs, increasing food security;
- Seed and animal fodder banks to prevent farmers from having to sell seeds and livestock early; replenished on local markets, they provide a source of income for producers;
- Agricultural equipment rental and repair services to increase farmers' productivity;
- Training centers to equip farmers, poor households, and youth with new knowledge and skills to improve the resilience of production and make a living in rural areas;
- Community radios providing access to information about government initiatives, weather forecasts, and experiences shared by peers;
- On-site meteorological services, providing local weather forecasts to inform farming and harvesting decisions;
- Microfinancing to enable rural producers and community members, including women, to realize potential investment opportunities or build alternative livelihoods;
- Administrative units providing operational support and guidance to local rural producers and cooperatives;
- A one-stop-shop for integrated services, helping to integrate and align programs and services from the national to the local levels; and
- Physical building facilities that can be used to deliver other social services and community engagement, including health and nutrition outreach activities, disaster relief coordination and distribution, and meeting space for local producer groups and women's cooperatives.

While the project delivered services across the 38 beneficiary communes prior to development of MPs, the MPs were developed to enhance the integrated service provision and provide a platform for sustaining service provision beyond the project term. The CAPCR projects closed in May 2021, and interviewees indicated that additional financing is being sought to continue and expand the CAPCR initiative and the implementation of MPs in additional targeted communes following their successful piloting through these projects.

Project stakeholders

The key stakeholders for this project include the Government of Niger and the project's implementing agencies, the National Council of Environment for a Sustainable Development (CNEDD); the General Directorate of Environment, Water and Forests of the Ministry of Water and Environment (MHE); the General Directorate of Territorial Management and Community Development of the Ministry of Planning, Territorial Management and Community Development (DGATDC); and the Ministry of Planning, Territorial Management and Community Development (MPATDC). The CNEDD, the agency responsible for coordinating the national policy on environment and sustainable development in Niger, oversaw project implementation of component 1. The MHE, a key institution in charge of the environment and natural resource management in Niger, and the DGATDC, a national implementing agency in Niger, were the key responsible agencies for project implementation for selected activities of component 2. The MPATDC provided oversight for the full project.[7] Additional project stakeholders include mayors, producer organizations, and farmers in the 38 targeted beneficiary communes.

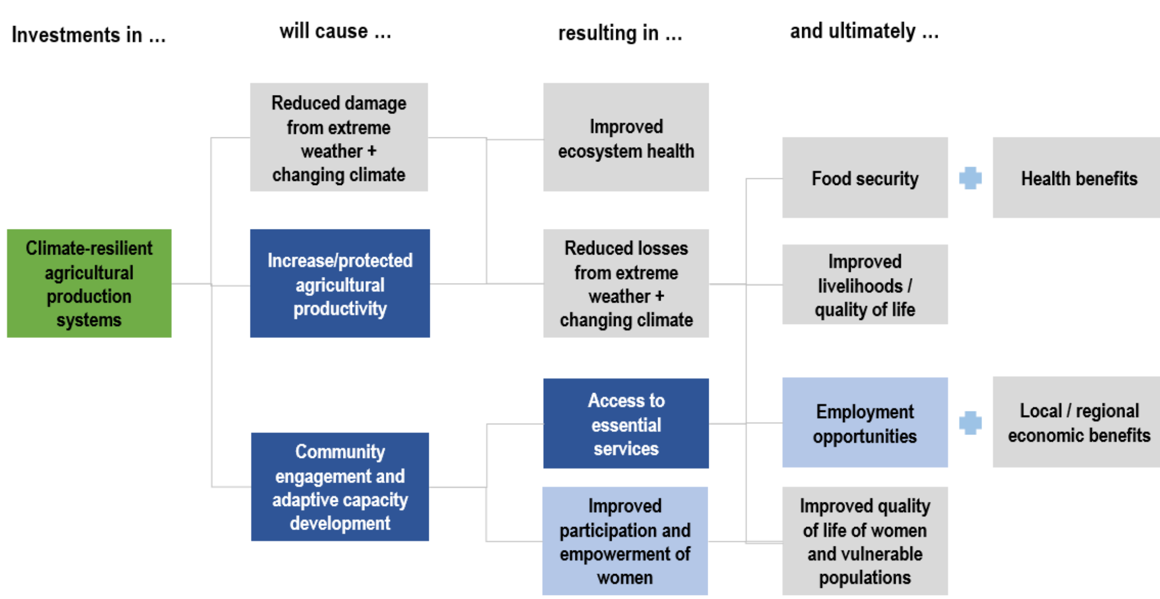
Development impact pathways and case study focus

The purpose of this case study is to analyze the development impacts (DIs) of PPCR investments in improving climate resilience of populations and production systems in Niger. Potential impact pathways for these projects as identified by the evaluation team through input from stakeholders and literature review are presented in Figure 1. The project's DIs are expected to be driven mainly by increased/protected agricultural productivity, enhanced community engagement and support for adaptive capacity development in institutions and populations, and reduced damage in agricultural production systems from extreme weather and a changing climate.

The **dark blue boxes** indicate the DIs quantitatively assessed in this case study: increased/protected agricultural productivity, community engagement and adaptive capacity development, and access to essential services. The **light blue boxes** indicate the DIs qualitatively assessed in this case study: improved participation and empowerment of women and employment opportunities.

The **gray boxes** indicate DIs that could be realized through this investment impact pathway, but were not assessed for one or more reasons, such as expected timeframe of impact, scale of project, or additional research and analysis requirements. They include reduced damage and losses from extreme weather and climate change impacts; improved food security; improved livelihoods/quality of life (including for women and vulnerable populations); health benefits; local/regional economic benefits; and improved ecosystem health.

Figure 12. Impact Pathways of Community Action Project for Climate Resilience in Niger



Of the broad list of DIs identified in our impact pathways, four were included in varying forms (metrics) in the available documentation across the projects included in this case study: improved climate resilience among rural producers and poor households (associated with enhanced adaptive capacity and access to essential services), improved climate resilience and productivity in agricultural production systems, improved climate resilience and productivity in silvopastoral production systems, and improved resilience by mainstreaming climate change into development strategies and institutions to support community engagement and adaptive capacity development (including at the local level). Silvopastoral production systems refers to practices that intentionally integrate trees and pasture and forage crops into a single system for raising livestock with substantial carbon sequestration benefits.[8]

Examples of applicable metrics for these DIs in the project documents include: "[number of] direct project beneficiaries (including rural producers and poor households and women)," "crop yield increase in the project's areas of intervention," "forage yield increase in the project's areas of intervention," and "existence of channels and/or institutionalized mechanisms allowing citizens to engage in actions on resilience to climate change through government agencies and other stakeholders." Forage productivity refers to crops grown specifically for grazing by livestock or to help make up seasonal shortfalls between feed demand and supply. Additional intermediate results metrics identified include: "additional agricultural areas with improved SLM (sustainable land management practices)," "additional silvopastoral areas with improved SLM," "number of sector policies which fully incorporate climate resilience," and "number of LDPs (Local Development Plans for communes) and AIPs (Annual Investment Plans for communes) incorporating climate resilience."

Development Impacts (Quantitatively Assessed): Performance to Date

Improved community engagement and adaptive capacity to enhance climate resilience among rural producers and poor households

The theory of change of the CAPCR projects holds that direct engagement of rural producers, poor households, and women to provide them with integrated, holistic services will enhance their adaptive capacity and resilience to climate change and variability. The project successfully delivered knowledge and resources to nearly half a million rural producers and poor households whose livelihoods are sensitive to the impacts of climate change.[9] As noted above, services were delivered through a holistic model based on innovative "Maisons du Paysan" community-based platforms.[10]

Table 1. Direct Beneficiaries of Engagement and Capacity Development Activities[11]

Beneficiary Groups (Households)	Original Target	Revised Target	Achieved Value
Rural producers	124,000	199,000	406,878
Poor households	56,000	81,000	86,358
Total beneficiaries	**180,000**	**280,000**	**493,236**

Through the projects, more than 400,000 rural producers were introduced to sustainable land and water management (SLWM) practices. Climate-resilient SLWM practices included facilitating producer use of enhanced seeds and fertilizers (covering 166,100 hectares of existing rainfed farmland). Use of enhanced agricultural inputs was coupled with technical assistance on appropriate SLWM techniques to increase water penetration, improve soil condition, and control invasive plants. Interviewees observed that these factors contributed to the increase in crop yields (see discussion below). Irrigated agriculture was also supported (with over 125,000 meters of irrigation network installed), and an additional 6,061 hectares were regenerated by digging half-moons, or semicircular ponds that help soil retain rainwater, and cultivating resistant crop varieties. Silvopastoral support included physical work to install fencing and make grazing corridors between tree or shrub rows on nearly 47,000 hectares. Technical assistance and training were also provided on locally adapted SLWM practices, including planting of fodder crops, establishment of pastoral half-moons, and management of grazing area rotations. Members of poor households not engaged in agro-silvoproduction were engaged in other capacity development activities to support livelihood development, skill building, and employment opportunities and strengthen their adaptive capacity. Capacity development activities included construction work to upgrade rural buildings and infrastructure such as schools and agricultural facilities to enhance resilience to climate impacts, as well as support to MP operations such as seed and fodder storage and management.

Table 2. Extent of SLWM Practice Adoption[12]

Climate-resilient SLWM practice	Reported area practice adopted
Enhanced seeds and fertilizers	166,100 ha
Irrigation network installed	125,000 m
Land regenerated with half-moon ponds to retain water for agriculture	6,061 ha
Silvopasture work to install fencing and make grazing corridors	47,000 ha

Project data collection and analysis indicate that the engagement of rural producers in training and capacity development activities and services led to high adoption rates of SLWM practices, which interviewees and project documents describe as an indication of improved climate resilience and adaptive capacity at the household and small producer level. A beneficiary survey was conducted in May 2021 with support from Niger's National Statistical Institute with a representative sample of 20 agricultural households in 77 villages in the project intervention zone. The survey found that 77 percent of rural producers benefitting from engagement and technical capacity development assistance support had adopted at least one of the SLWM techniques introduced.[13] The ICR and several interviewees indicated that the high implementation rate (well above the initial SLWM adoption target of 60 percent) can be attributed to factors including the proper testing and adaptation of SLWM techniques to local conditions and the provision of technical assistance on SLWM practices with social protection measures (e.g., access to seed banks, access to microfinance, provision of alternative livelihoods). Adoption of these agricultural SLWM practices was credited in project documents and by interviewees with increasing crop yields in areas targeted by the project interventions; similarly, use of these silvopastoral SLWM practices was credited with producing documented increases in forage yields of biomass for livestock fodder (see below).

Improved institutional capacity to support community engagement and access to essential climate resilience and social protection services

Some project results metrics focused on institutional development and capacity building as an important DI supporting access to essential services needed for climate resilience. One intermediate outcome linked to the project's development objectives was to mainstream climate resilience into development strategies and institutions at the national and local levels. One indicator tracked the explicit incorporation of climate resilience issues and activities into communes' Local Development Plans (LDPs) and Annual Investment Plans (AIPs). By May 2021, all 38 communes participating in the project had incorporated strategies and budgeting to build climate resilience into LDPs and AIPs. As another indicator of institutional development, the project team tracked the development and operationalization of MPs across the 38 target communes. As of May 2021, eight MPs were fully operational, and five were partially operational. While not formally monitored, project documents and interviews referenced a wide range of essential services (and associated benefits) provided by the MPs.

Another project indicator focused on the "existence of channels and/or institutionalized mechanisms allowing citizens to engage in actions on resilience to climate change through government agencies and other stakeholders."[14] The indicator was defined as "the existence of a stakeholder citizen engagement body developed and implemented for climate resilience." Prior to project closing in 2021, a citizen engagement plan was developed (and is operational) to consolidate existing grievance redress mechanisms and community monitoring systems into an engagement channel linked to the MPs.

Increased agricultural productivity resulting in higher crop yields

Crop yields in CAPCR project areas were consistently higher (59 percent on average) than crop yields in control sites not addressed by the projects.[15] A rigorous evaluation methodology was developed and implemented to assess agricultural productivity results, using an approach that compared yields in project sites and non-project control sites.[16] Annual sampling campaigns of primarily millet and sorghum were systematically implemented from 2015 to 2020. Samples were collected from 10-by-10-meter plots, which were then dried and weighed. A robust method was employed to carefully select project sites and control sites based on similarities of soil and precipitation characteristics, and a consortium of institutional and community-based stakeholders participated in the data collection, which was collated and analyzed by the National Center of Ecologic and Environmental Monitoring. While yields dropped in 2018 due to unreliable rainfall, outcomes improved in 2019 and again in 2020 when rainfall improved. Interviewees attributed the increased yields to factors including use of improved drought-resistant seeds, mineral fertilization, implementation of SLWM techniques, and agricultural extension services to enhance the quality of real-time production decisions. Table 3 summarizes annual crop yields in project and control sites over time.

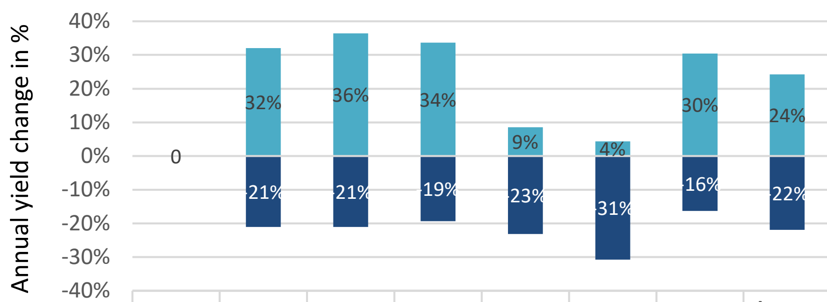
Table 3. Crop Yields in Project and Control Sites[17]

	2014 (pre-project)	2015	2016	2017	2018	2019	2020	Average
Annual yields (kg/ha)								
Yields in project sites	372	491	508	497	404	388	485	462
Yields in control sites	372	294	294	300	286	258	312	290
Difference in yields (%)	0	67	73	66	41	51	56	59

The agricultural productivity indicator originally proposed for the project focused on "reduced cereal deficit in targeted agro systems within the area covered by the project," with a target of reducing the cereal deficit to 30,000 tons a year from a baseline of 100,000 tons. However, the indicator was revised in 2014 due to the high variability in crop and forage deficits caused by factors beyond the project's control, which made it difficult to define operational baselines to gauge impacts.[18]

To better assess the climate resilience impact of project activities, the project team analyzed the annual yield changes in treated sites and control sites each year and compared this actual yield with forecasted 2015–2020 yields developed in 2014 as a baseline. The analysis shows that project sites performed above the baseline every year with an average overperformance of 24 percent. Meanwhile, the control group consistently performed below the baseline. This results in an average spread of 46 percentage points between the yield change in treated sites and the yield change in control sites. The analysis shows that crop yields in project sites have been more resilient to external factors, such as variability in temperature and rainfall, compared with control sites. (The same analysis could not be performed for forage yields, as the project team did not have access to similar historically forecasted data.)

Figure 13. Annual Crop Yield Changes in Project Sites and Control Sites Compared with 2014 Forecast (372 kg per ha)[19]



	2014	2015	2016	2017	2018	2019	2020	Average
Annual yield changes in Project sites	0	32%	36%	34%	9%	4%	30%	24%
Annual yield changes in control sites	0	-21%	-21%	-19%	-23%	-31%	-16%	-22%

Increased silvopastoral productivity resulting in higher forage yields

Forage yields in project areas performed better than in control sites every year since 2015, though the effect of improvements tended to wane over time. While it is not clear why improvements waned, one interviewee observed that acute seasonal financial and time pressures on some rural producers may result in relaxed implementation of SLWM practices over time if there is no refreshed training or extension outreach. A similar comparative method was used for assessing forage yields, with annual sampling in project sites and non-project control sites. Following the initial implementation of physical structures and sustainable practices in 2014 and 2015, the trend shows a steady narrowing between yield outputs in project and control sites from 2016 to 2019. In 2020, project areas produced 31 percent more biomass than control sites, even as both groups benefitted from improved yields due to good rainfall (Table 4).

Table 4. Forage Yields in Project and Control Sites[20]

	2014 (pre-project)	2015	2016	2017	2018	2019	2020	Average
Annual yields (tDM/ha)								
Project sites	n.a.	1.15	0.61	0.61	0.58	0.84	1.48	0.88
Control sites	n.a.	1.00	0.40	0.43	0.48	0.75	1.12	0.70
Difference in yields (%)	0	14	50	44	22	11	31	26

Table 5. Summary of Quantified DI Benefits Assessed

DI	Included in original project documents?	Metric /KPI	Method of assessment
Community Engagement/ Beneficiary Resilience Capacity Development/ Access to Services	Yes	Direct project beneficiaries (#) Beneficiaries implementing SLWM practices (%)	Estimation included in the project documents and interviews
Institutional Resilience Capacity Development and Service Provision	Yes No	LDPs and AIPs incorporating climate resilience (#) Maison du Paysan constructed and fully operational (#)	Estimation included in the project documents and interviews
Institutional Community Engagement Mechanisms	No (added in 2019)	Existence of channels and/or institutionalized mechanisms allowing citizens to engage in actions on resilience to climate change through Government agencies and other stakeholders (Yes/No)	Estimation included in the project documents and interviews
Agricultural Productivity	Yes (although indicator was revised in 2014 to enable more accurate comparisons)	Crop yield increase in the project's areas of intervention (%)	Estimation included in the project documents; robust assessment methodology implemented using sampling and measurement of output of project sites and non-project control sites
Silvopastoral Productivity	Yes (although indicator was revised in 2014 to enable more accurate comparisons)	Forage yield increase in the project's areas of intervention (%)	Estimation included in the project documents; robust assessment methodology implemented using sampling and measurement of output of project sites and non-project control sites

Development Impacts (Qualitatively Assessed): Performance to Date

Improved participation and empowerment of women

Project documents and interviews indicated that project activities were explicitly implemented with a gender-sensitive approach. The evaluation team found limited quantitative data on the gender dimensions of participation in the projects, but the project's Implementation Completion and Results Report indicates that 48 percent of project beneficiaries were women.[21] The project team also estimated that the share of smallholder women farmers (not necessarily heads of household) within 20 kilometers of a Maison du Paysan who had improved access to agricultural services was 38 percent.[22]

Project documents also indicate that all established MPs developed gender strategies to improve women's access to services (which was confirmed in interviews).[23] However, some interviewees said they had mainly seen men at the MPs during their visits. Similarly, a report from a World Bank supervision mission site visit in November 2020 noted "that women were generally absent from the site of the MP."[24] With regard to evidence assessing the empowerment of women, the evaluation team only found limited observations from interview data. For example, interview data from two female farmers/producers and the president of a community women's group indicate that each of these women found that the training (e.g., on SLWM practices, including crop management and drip irrigation) provided through the MPs was useful. Two of the women indicated that the access to seeds and animal feed had reduced their costs and improved their household economic conditions.

Improved employment opportunities

Project documents indicate that the resiliency of poor households without productive means improved through opportunities for paid labor. For example, as part of the projects, unskilled workers helped protect and rehabilitate critical socioeconomic infrastructure that was vulnerable to wind, floods, dune movements, and other climate and extreme weather impacts. Infrastructure improved under the projects included 235 facilities, such as health centers, child nutrition centers, maternity hospitals, primary schools, markets, slaughterhouses, vaccination parks, feeder roads, water supply systems, small water infrastructure, food storage facilities, among others. In addition, project documents note that another important job creation initiative was linked to the production of animal fodder (feed supplements) from agricultural residues, such as cereal straw and crop stalks. In 2020, the quantity of animal feed supplements produced by the project was estimated at 42,105 tons.[25] Project documents include an estimate that approximately 20,000 households benefited from paid labor opportunities.[26] In addition, some interviewees mentioned that operation of the MPs creates some temporary and permanent employment opportunities. The evaluation team did not find evidence to help understand the magnitude of employment benefits and their impact on livelihoods.

Other Implied DIs (Not Assessed)

Other potential impacts, including reduced damage and losses from extreme weather and changing climate, food security, improved livelihoods/quality of life (including for women and vulnerable populations), health benefits, local /regional economic benefits, and improved ecosystem health, were mentioned briefly in project documents and stakeholder interviews. The evaluation team did not find quantitative or qualitative data to assess these DIs. Additional reflections on some of these implied DIs are provided below.

Food security

Given the stated objective of achieving a "transformative impact" on food security,[27] it is worth noting that approaches for assessing food security were discussed in the Implementation Completion and Results Report.[28] The report observes that increased yields are output indicators and do not indicate where and for whom food security has improved. The report further notes that a complementary approach would be needed at the household level to survey food security within the project areas, using one or more of the four main types of food security indicators: (a) food consumption, (b) coping strategies, (c) food expenditures, and (d) malnutrition. It notes that this would allow the project to triangulate whether increased yields have led to improved food security for households in the project areas.

Second, the report notes that while high rainfall variability is normal, but intensifying due to climate change, during the years of project implementation, extreme events such as prolonged droughts or floods did not occur on a scale broad enough to significantly affect food security. To consider the results in a wider context, the report team consulted data from the Famine Early Warning Systems Network. The data indicated that on a scale of 1–5, Niger had not experienced severe food insecurity at the level of an emergency (4) or a famine (5) from 2015 onwards. However, food insecurity at the level of stress (2) or crisis (3) had occurred regularly due to droughts and floods. The report team concluded: "As this also affected project areas, results, when compared with control sites, can be understood to have increased resilience of yield outputs to climate variability. The outcomes have not been tested against more intense climate shocks."[29]

Improved livelihoods, quality of life, and health

These DIs were mentioned in several project documents and in stakeholder interviews although they were not elaborated on. It was generally assumed that improvements in agricultural yields, employment opportunities, access to essential services, and community engagement would also lead to these outcomes, although efforts were not made to directly measure or assess them. In a project context with interventions focused on the community level, these outcomes would likely be best understood at the household level and would require household surveying or other approaches to assess changes. In addition, local/regional economic benefits and improved ecosystem health would require data collection, modeling, and/or other analyses to assess. No negative development impacts or unintended consequences were identified in project documents or interviews.

Barriers to Building Capacity for Climate Resilience and Realizing DIs[30]

Several barriers to achieving DIs within CIF-PPCR projects were identified.

Insufficient attention and support to project implementation and sustainment at the local level

The CAPCR projects highlighted the importance of careful attention to supporting project implementation at the local level. Climate resilience interventions typically require substantial, on-the-ground adaptive management and coordination activities to ensure that implementation progress is made. Three interviewees observed that in project sites that did not receive focused management and coordination support, implementation progress stalled or lagged. One interviewee observed that the Maison du Paysan building in one commune sat unused for months, with equipment still in its packaging, until a new management and implementation approach was established for CAPCR. To support sustainable local program management, coordination, and infrastructure, the CAPCR project team redesigned its implementation approach to focus on a coaching model with results-based management practices. Coaching for MP implementation teams and mayors focused on leadership development, problem solving, results-based management, and communication and coordination between local and national partner institutions. A study conducted by the CAPCR project team found significant differences in development outcomes and impacts across MPs that were and were not using the "coaching + results-based management" system, prompting efforts to expand use of the system.[31] With regard to the waning productivity benefits of silvopastoral practices over time, one explanation could be the need for beneficiary retraining and other support prompts and mechanisms to ensure sustained attention to silvopasture and SLWM practices over time.

Ineffective coordination between national and local institutions to support aligned project implementation

Several interviewees observed that ineffective communication between officials in national institutions and local implementing parties can hinder the effective implementation of climate resilience projects. One interviewee noted that climate resilience programs require substantial problem-solving and adaptation at the local level as circumstances and issues change. Local and national institutions need to be nimble and communicate and coordinate effectively with one another. Interviewees noted that the weekly and monthly coaching meetings provided a useful mechanism for identifying and facilitating communication and coordination needs, including between local MP teams and national institutional partners.

Cultural barriers that limit women's participation and lead to gender-related gaps in outcomes

Some interviewees observed that cultural and other barriers can limit women's participation and lead to gender-related gaps in outcomes. One interviewee noted that even when project sites develop specific gender inclusion strategies, a range of factors can inhibit effective implementation of the strategies. One interviewee encouraged efforts by project teams (or MP implementing teams) to explicitly identify and address barriers to women's participation. The World Bank's Systematic Country Diagnostic has noted that plots managed by women produce 19 percent less per hectare than plots managed by men. Key factors identified included challenges in accessing, using, and supervising male farm labor; (b) lower use of chemical fertilizers by women; and (c) men's higher land ownership rates.[32] Enhancing DIs for women is thus likely to require increased attention to these and other factors.

Delays in securing support for post-intervention follow-on activities

Several interviewees noted that there have been delays in securing financing to support the sustained implementation and scaling up of the CAPCR program design and the Maison du Paysan model with the coaching + results-based management system. Some interviewees noted that while MP operations continue in the communes where MPs were fully established, the project follow-on delays are missing important opportunities to enhance implementation support and scale the model to more of the targeted 38 communes.

Future Opportunities for Realizing DIs through Building Capacity for Climate Resilience

The CAPCR projects have supported the Government of Niger to develop and pilot a powerful and effective model for delivering climate resilience services to rural producers and poor households. The Maison du Paysan model provides an integrated platform—including physical infrastructure and operational and management systems—for delivering a broad range of services to boost farm productivity and deliver social protection services, with potential for expansion over time. Some interviewees also noted that the MPs provide a tangible symbol of government and institutional services and benefits (e.g., "representing that the state is present in peoples' lives"), which can enhance social stability, which benefits development outcomes. Furthermore, the "coaching + results-based management" system will need to be sustained and expanded to ensure effective operationalization of the service platforms and the high levels of development impacts experienced in the piloting phase of CAPCR. In Niger, the primary opportunity for realizing DIs found by this case study research is to expand (to additional communes) and sustain implementation of the Maison du Paysan climate resilience and social protection service delivery platforms.

As CIF and its partners consider opportunities to enhance the realization of DIs in climate resilience capacity building initiatives in poor countries, three important aspects of the CAPCR project in Niger may offer compelling adaptable models:

Integrated rural service delivery platforms with physical building structures

The MPs provide platform infrastructure in rural communities that can support delivery of a broad range of services relevant to enhancing climate resilience capacities, including agricultural training and extension services, equipment sharing and repair services, and microfinance services, among many others. The physical buildings help protect seeds, fodder, and other agricultural inputs and outputs, making them locally accessible and protected from the weather. The buildings also provide flexible meeting spaces for a wide range of local development activities and services.

Coaching, results-based management, and leadership development model

Nearly all interviewees referenced the coordination and communication challenges that can plague implementation of climate resilience initiatives and integrated service platform models. Most credited the mid-project adjustment to develop a strong coaching program, coupled with results-based management, problem-solving, and leadership development activities, as perhaps the most vital element of the success of the MP model. The CAPCR project team, including representatives from the Government of Niger, developed multiple guidebooks and training resources to support implementation of the "coaching + results-based management" system. It is important to note that implementing this type of system does require sustained investment over time in human resource capacity to ensure and support its effective implementation.

Robust assessment methods and partnerships

The CAPCR projects included development of and investment in robust assessment methodologies, including to assess agricultural productivity benefits and to assess program beneficiaries. While they can take substantial effort and be somewhat costly, robust analyses of new climate resilience programs can be vital to support learning and adjustments related to program implementation, and to building a strong case for sustaining, expanding, and scaling the programs. The CAPCR projects also engaged key government statistical and monitoring agencies in the assessment work, further strengthening and diversifying government commitment and capacity to support the work.

Future Research

CIF could consider additional research to facilitate the analysis of additional DIs associated with Building Capacity for Climate Resilience in Niger:

- Household-level studies to assess changes in food security (i.e., food consumption, coping strategies, food expenditures, and malnutrition), livelihoods, and quality of life, to enhance understanding of how adoption of climate-resilient agricultural practices and improved yields are impacting these outcomes and household wealth and income.
- Increased access to essential services, to determine changes in access to specific types of services (e.g., training on SLWM practices, access to agricultural inputs, microfinance services, equipment procurement and repair services) and the associated impacts and benefits of these services. Enhanced measurement and analysis of access to specific types of services provided by the MP platforms could inform tailoring and improvement of the marketing and provision of specific services, including for women and youth.
- Reduced damages and losses from extreme weather and changing climate conditions.
- Local regional and economic benefits, to determine how many new direct and indirect jobs were created through the implementation of CAPCR at different project sites.

Sub-Appendix 11A

Interviewee List[33]

Organization	Designation	Name
Climate Investment Funds	Climate Change Specialist for PPCR	Lorie Rufo
World Bank	Lead Environmental Specialist in the Environment and Natural Resources Global Practice	Dahlia Lotayef
World Bank	Senior Operations Officer, Collaborative Governance	Lili Sisombat
World Bank	Natural Resource Management Specialist	Mirko Ivo Serkovic (Written input provided)
Independent Consultant	[Supported MP coaching implementation and project completion and results analyses]	Annick Lachance
Government of Niger, Community Action Project for Climate Resilience (PACRC)	Monitoring and Evaluation Manager	Yayé Amadou (Pre-recorded interview)
Government of Niger, Community Action Project for Climate Resilience (PACRC)	National Coordinator	Inoussa Dambagi (Pre-recorded interview)
Government of Niger, Community Action Project for Climate Resilience (PACRC)	National Coach	Dr. Soumana Saïbou (Pre-recorded interview)
Mayor of Falwel	Mayor in one community with a MP	Diori Abdoulraman (Pre-recorded interview)
Falwel Maison du Paysan	Technical Coordinator, Falwel MP	Bokata Boubé (Pre-recorded interview)
Banimate Women's Group	President	Taïbatou Idrissa (Pre-recorded interview)
	Farmer/producer	Haïma Oumadou (Pre-recorded interview)
	Farmer/producer	Mariama Séini (Pre-recorded interview)
	Farmer/producer	Zakounoma Gabdakoy (Pre-recorded interview)
	Farmer/producer	Halissa Hassa (Pre-recorded interview)

Endnotes

[1] See country profile by the United Nations World Food Program: https://www.wfp.org/countries/niger.
[2] World Bank (2011). *Project Appraisal Document on a Proposed Concessional Loan,* December 2011. Available at: https://documents1.worldbank.org/curated/en/931201468097469292/text/658970PAD00PUB090201100R20110027701.txt
[3] World Bank (2011).
[4] World Bank (2021). *Implementation Completion and Results Report, Report No: ICR00005589*, November 2021. Available at: https://documents1.worldbank.org/curated/en/286861638456216797/pdf/Niger-Community-Action-Project-for-Climate-Resilience-Project.pdf.
[5] World Bank (2021); see Theory of Change/Results Chain on page 9.
[6] World Bank (2017). *Project Paper on a Proposal Additional Financing Loan*, 2017, available at https://pubdocs.worldbank.org/en/621391531554843559/6304-PPCR-Niger-XPCRNE075A-IBRD-Niger-CAPCR-Additional-Financing-Project-Document.pdf
[7] World Bank (2011). *Project Appraisal Document on a Proposed Concessional Loan.*
[8] See Zeppetello, L.R.V., Cook-Patton, S.C., Parsons, L.A. et al. Consistent cooling benefits of silvopasture in the tropics. *Nat Commun* 13, 708 (2022). https://doi.org/10.1038/s41467-022-28388-4. Also see California State University Chico, Center for Regenerative Agriculture and Resilient Systems (https://www.csuchico.edu/regenerativeagriculture/ra101-section/silvopasture.shtml)
[9] World Bank (2021). *Implementation Completion and Results Report*.
[10] The evaluation team did not find a precise definition of "beneficiaries" in CAPCR project documents, although interview information suggests that the reported number of rural producer beneficiaries refers to the actual number of individuals who participated in programs/received direct services from the MPs and associated CAPCR-supported programs. Project documents (i.e., ICR Report) indicate that the number of poor household beneficiaries includes individual recipients who received social protection services (i.e., cash transfers, food vouchers) and/or paid labor opportunities associated with CAPCR-supported programs.
[11] World Bank (2021), p. 14. The ICR indicates that these household beneficiaries translate into 2.415 million individual direct beneficiaries, including 1.155 million women. It does not indicate how the data on beneficiaries were derived.
[12] Ibid, p. 14.
[13] Ibid, p. 14.
[14] The unit of measure was set as "yes/no."
[15] World Bank (2021). *Implementation Completion and Results Report*, p. 16, Table 3.
[16] World Bank, *Méthodologie Évaluation des Systèmes de Production Agro-Sylvo-Pastoraux.* Also discussed in World Bank (2021). *Implementation Completion and Results Report*.
[17] World Bank (2021). *Implementation Completion and Results Report*, p. 16, Table 3.
[18] Multiple interviewees noted this shift in indicators to help control for exogenous factors; this change is also noted in the projects' ICR.
[19] World Bank (2021). *Implementation Completion and Results Report*, p. 17, Figure 2.
[20] World Bank (2021), Table 4.
[21] World Bank (2021), p. 34. The ICR suggests that the 493,236 household beneficiaries (rural producers and poor households) translate into 2.415 million direct individual beneficiaries, of whom 1.155 million (or 48%) were female. The ICR does not indicate the source for these data or how they were derived.
[22] World Bank (2021). *Implementation Completion and Results Report*.
[23] World Bank (2021), p. 21.
[24] Ibid.
[25] World Bank (2021), p. 15.
[26] World Bank (2011). *Project Appraisal Document on a Proposed Concessional Loan,* pp. 36–37. The PAD defines a paid laborer as a paid individual working an average of 4–5 hours/day over a period of at least 30 days/year.
[27] World Bank (2011).
[28] World Bank (2021). *Implementation Completion and Results Report, Report No: ICR00005589*, p. 30.
[29] World Bank (2021). *Implementation Completion and Results Report, Report No: ICR00005589*,, p. 17.
[30] Insights about enabling the achievement of DIs are included in the section on Future Opportunities for Realizing DIs through CAPCR in Niger.
[31] Dr. Soumana Saïbou (Government of Niger and World Bank). *Maison des Paysans: Synthèse étude comparée des MP avec et sans coaching*. February 15, 2021. One interviewee observed that development of the coaching + results-based management

system was informed by the following publication: Robert H. Schaffer, Ronald N. Ashkenas (Jossey-Bass, 2005). "Rapid Results: How 100-Day Projects Build the Capacity for Large-Scale Change."
[32] World Bank (2021). *Implementation Completion and Results Report*, p. 20.
[33] Pre-recorded interviews were conducted by the World Bank of key CAPCR stakeholders and included some discussion of development impacts. Interview recordings were made available to the evaluation team, as noted in the table.

12. Thailand Deep-Dive Case Study: Development Impacts of Private Sector Utility-Scale Wind Power

Project Details	Funding
Name: Clean Technology Fund (CTF) Private Sector Renewable Energy Program and Renewable Energy Accelerator Program **Country:** Thailand **CIF Program Area:** CTF **Bank approval:** 2009 **Effective since:** 2012 **Actual closing:** 2016 **MDB:** Asian Development Bank (ADB)	**Total Value:** $163.59 million plus equity **CIF:** $34 million **Co-financing total:** $129.59 million **ADB:** $57.15 million **Bank of Ayudhya:** $72.44 million) **Instrument type:** Grant, Loan **Sector:** Private

Key Highlights

- Thailand's Integrated Energy Blueprint sets a target of 3,002 MW of installed wind power capacity by 2036. The CIF projects directly installed 88.5 MW and facilitated the installation of additional private wind facilities. As of 2020, Thailand had 1,510 MW of installed wind capacity.
- CIF's Clean Technology Fund (CTF) supported the successful construction of two utility-scale wind-power facilities: Theppana (7.5 MW) and Subyai (81 MW). CTF provided a total of $4 million in funding for the Theppana plant and $30 million for the Subyai facility. The projects were also supported by ADB and the Bank of Ayudhya.
- The CTF-funded projects were the first movers for utility-scale wind power in Thailand. CTF support was important in overcoming the financial and regulatory barriers that had prevented earlier wind-power activities and in facilitating future investments in wind power.

Topline Findings on Development Impacts

- **Market development:** Installed wind power capacity has increased from less than 10 MW in 2008 to 1,510MW in 2020. This expansion would not have been possible without demonstration of the financial viability of wind power and adaptations to the regulatory environment that were facilitated under the Theppana and Subyai projects. These first-mover utility-scale wind power projects paved the way for future projects.
- **Employment gains**: Combined, the two CIF-financed facilities created 669 construction jobs and 38 permanent positions.
- **Income diversification**: Local farmers leased land to the plants, earning higher rents than the expected returns for farming cassava, helping to localize the economic benefits of the wind projects in the surrounding communities.
- **Diversification of energy sources**: The two plants provided an alternative to imported natural gas or coal generated energy and helped unlock the potential for future wind projects.

- **Expanded infrastructure**: Construction efforts included expansion of community-accessible roads and improvements to water management systems.
- **Acquisition of transferable job skills:** Both facilities offered opportunities for local residents to gain skills related to wind power operations through scholarships and internships. The Theppana plant trained four plant operators.
- **Community engagement:** The projects invested in local infrastructure and sponsored a variety of corporate social responsibility activities to benefit and engage the local community.
- **Health benefits from reduced air pollution:** The expansion of renewable wind energy displaces the emission of air pollutants from natural gas and coal, which can cause adverse health impacts. To understand the economic benefits of these avoided health impacts, economists may apply the value of statistical life (VSL). The health benefit measured with the VSL of the Theppana and Subyai facilities alone is estimated at $1.46 million—and the potential benefits if Thailand meets its national wind energy goals are substantially larger.
- **Capacity building**: CTF and ADB provided technical expertise to increase the capacity of Thai financial and regulatory institutions with regards to wind power and renewable energy.

Climate Investment Context and Overview

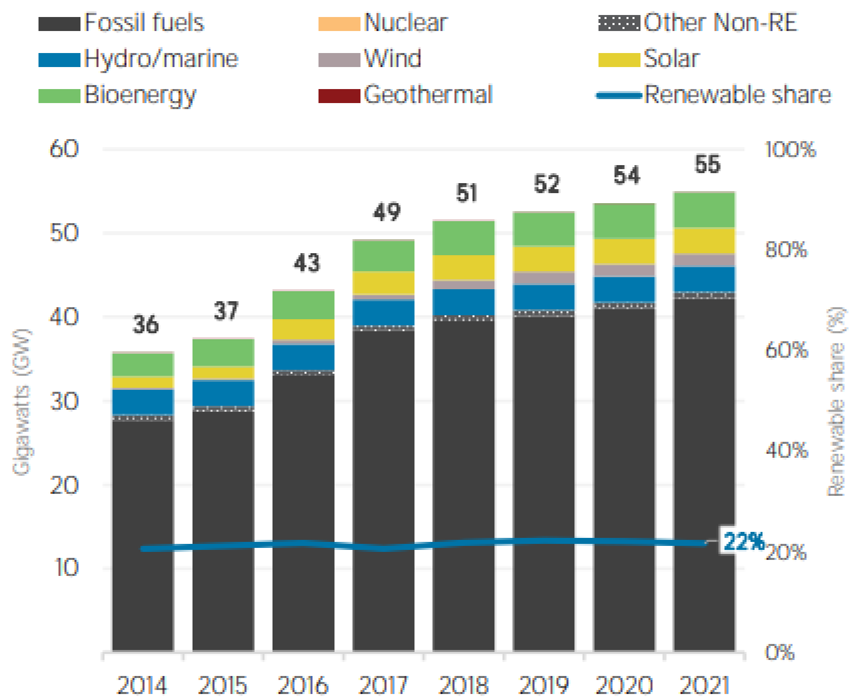
Thailand is the second-largest economy in Southeast Asia, after Indonesia, with a gross domestic product (GDP) of US$506 billion and a population of 71.6 million in 2021, just over half of which is concentrated in urban areas.[1] With GDP nearly tripling from 2000 to 2010—from US$120.3 billion to $341.1 billion—energy use has grown significantly as well. From the 1990s to 2010s, energy consumption and electricity demand grew at an annual average of 6 percent and 9 percent, respectively.[2] In 2010, before this project went into effect, fossil fuels made up 80.3 percent of Thailand's total energy supply, and most of the power supply came from gas (75.1 percent) and coal (18.6 percent), while only 5.6 percent came from renewables.[3]

As of 2008, Thailand had only 29.1 GW of installed renewable energy generation, mainly hydropower and biomass. Less than 10 MW of solar and wind energy were installed.[4] Heavy dependence on fossil fuels made the energy sector Thailand's top emitter of greenhouse gases (GHGs) by far, producing an estimated 216.9 million tons CO_2e in 2008, about 72 percent of the country's total emissions.[5]

There are also significant energy security concerns about Thailand's reliance on gas, as by 2011, domestic natural gas reserves were already projected to last less than 20 years.[6] Absent a shift in energy supply, Thailand would increasingly depend on politically unstable Myanmar to provide natural gas. The country's coal resources are also of concern, as it is mainly lignite, which has high sulfur content and low energy potential, exacerbating the damage of the GHG emissions already associated with coal.[7]

Both to diversify the country's energy mix and to reduce the harmful impacts of GHG emissions, Thailand developed a National Strategy for Climate Change (2008–2012) and a series of strategies that culminated in the 2014 release of the Thailand Integrated Energy Blueprint (2015–2036).[8] The Blueprint established goals to increase the total installed power capacity to 70,355 MW in 2036 and increase the share of renewable energy to 30 percent, including 3,002 MW of installed wind capacity. Figure 1 shows the progress on these Blueprint goals from 2014 to 2021.

Figure 1. Installed Electricity Generation Capacity in Thailand



Source: International Renewable Energy Agency (IRENA).[9]

To meet the targets established in the Blueprint, it was necessary to significantly scale up wind power generation. In 2011, the country's installed wind power capacity was only 7.3 MW, coming from a few turbines installed on university campuses, research sites, and the Ministry of Energy's Department of Alternative Energy Development and Energy Efficiency (DEDE) facilities. There were no utility-scale wind projects in the country.[10] Much of the country has low wind speeds and is not suitable for wind power installations, but in certain regions in the northeast and southwest the topography creates wind speeds of 5–7 meters per second in some areas. In 2011, researchers from Silpakorn University working for the DEDE estimated a country-wide wind power potential of 6,000 MW (potentially up to 17,000 MW with more advanced turbines).[11] Thus, while the targets established in the Blueprint were ambitious, they are also well within the total potential of the country.

The Thai government implemented several policies to promote the growth of renewable energy generation, particularly for small power providers (SPPs) and very small power providers (VSPPs).[12] Since 2004, the Thailand Board of Investment (BoI) has provided tax exemptions for alternative energy projects, and in 2007, a feed-in-tariff went into effect under the Adder Program. The initial design for the Adder Tariff augmented wholesale electricity prices for SPPs and VSPPs. The program has since been revised, but prior to 2015 wind power projects could receive 3.5 additional THB per kilowatt-hour (about

$0.11) for the first 10 years of commercial operation.[13] However, these incentives alone were not sufficient to incentivize private, utility-scale wind power projects in the country.

Purpose and scope of the case study

In 2009, CIF, through CTF, endorsed the initial Country Investment Plan for Thailand, supporting the country's clean energy transition.[14] The plan included $300 million in CTF funding to promote utility-scale renewable energy projects.[15] As part of this plan, CTF supported two wind power plants in Thailand: Theppana and Subyai, in partnership with the Asian Development Bank (ADB). The Theppana project was the first utility-scale power plant built in Thailand. Construction on the 7.5 MW facility started in September 2012, and the plant began operations in July 2013. Following the success of Theppana, CTF and ADB funded the 81 MW Subyai project, which began operations in 2016. Both projects are in Chaiyaphum province in central northeastern Thailand.

This case study assesses the development impacts (DIs) resulting from the Theppana and Subyai projects. Specifically, this case study considers the impact of privately funded wind power projects that were facilitated by CTF.[16]

Development Impact Pathways and Case Study Focus

The primary objectives of the Theppana and Subyai projects were to contribute to Thailand's clean energy transition by increasing the energy generated through wind resources. These two projects aimed both to add 88.5 MW of wind power capacity, and to demonstrate the viability of utility-scale wind. As the first-mover projects, they facilitated future, privately funded utility-scale wind projects by easing the regulatory challenges and generating interest from financing institutions.

The projects also created a range of DIs. They addressed regulatory barriers that had discouraged previous wind projects and demonstrated the financial viability of wind to reluctant investors, facilitating future investments in utility-scale wind plants. Investments in the wind facilities increased economic activity in local communities, providing jobs and business opportunities and funding infrastructure development. The projects facilitated positive relationships with impacted communities by supporting a variety of community development projects. In addition, the projects had health benefits by reducing air pollution from fossil fuel power generation. Subsequent private investments significantly scaled up these benefits.

The pathways for realizing these DIs are shown in the impact pathway model in Figure 2. The **dark blue boxes** indicate the DIs quantitatively assessed in this case study: health benefits (from improved air quality), market development, and employment opportunities. The **light blue boxes** indicate the DIs qualitatively assessed in this case study: diversification of energy sources, diversified incomes, local/regional economic benefits, expanded infrastructure, acquisition of transferable job skills, community engagement, and capacity building. The **gray boxes** indicate DIs that should follow from the projects, but are either too long-term to assess currently, and/or would require additional research and analysis to address. These include energy sector resilience, lower fuel imports, gender benefits, and access to essential services.

Figure 2. Impact Pathways for Utility-Scale Wind Energy Development

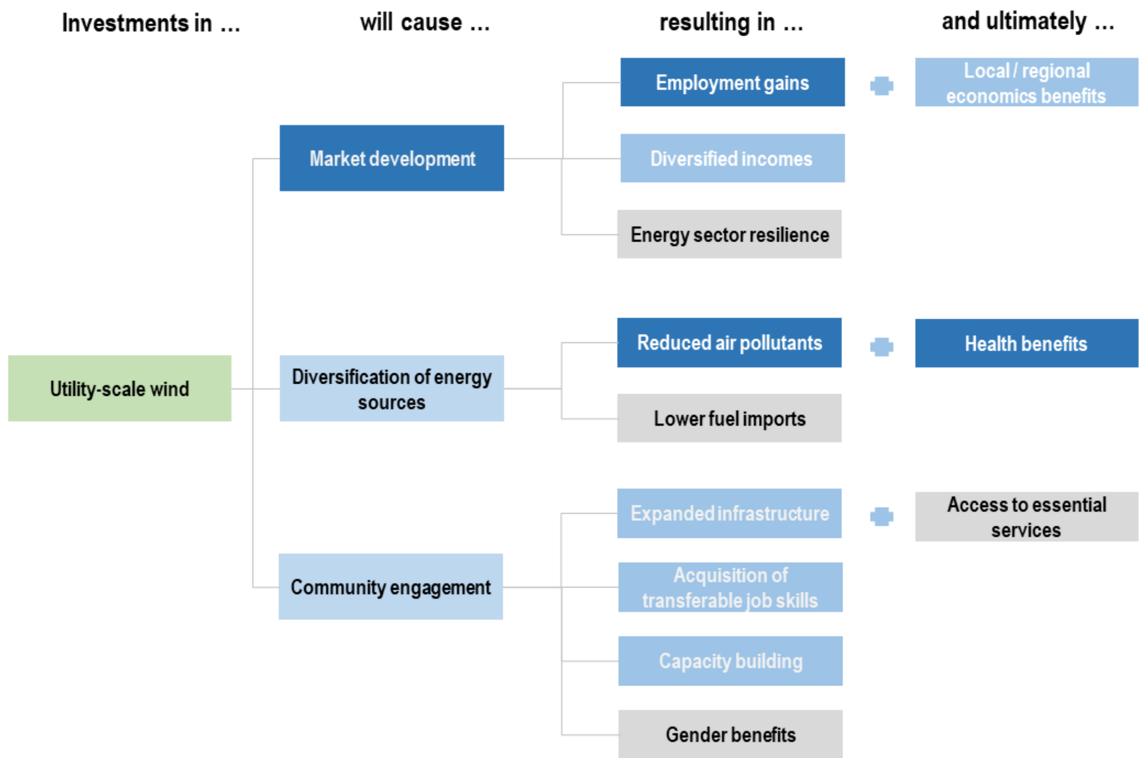


Table 1 shows whether the DIs are noted in project documents as potential outcomes and/or are actively tracked and measured.

Table 1. Utility-Scale Wind Power DIs

DI	In Project Documents?	Tracked by Project?
Economic		
Employment gains	YES	YES
Diversified income	NO	NO*
Local/regional economic benefits	YES	NO
Market		
Diversification of energy sources	YES	YES
Market development	YES	YES
Capacity building	YES	YES
Social		
Expanded infrastructure	YES	YES
Acquisition of transferable job skills	NO	NO*
Community engagement	YES	NO*
Gender benefits	NO	NO
Health benefits	YES	NO
Reduced air pollution	YES	YES
***DI reported in 2018 CIF case study, but not in project reports.**		

Stakeholders

Table 2 describes the roles of key stakeholders. In addition to CTF and the ADB, there were several key partners in the Theppana and Subyai projects. The primary project developer was the Electricity Generating Public Co. Ltd (EGCO). EGCO operates renewable and non-renewable power plants throughout Southeast Asia and Australia. EGCO partnered with ProVentum International (PVI), an international wind developer, to pursue wind power projects in Thailand.

For the Theppana project, a special purpose company, the Theppana Wind Farm Company, was established, with ownership split between EGCO (90 percent) and PVI (10 percent).[17] The managing project team for Theppana also included representatives from Goldwind Science, a Chinese wind turbine manufacturer that was contracted to build the three 2.5 MW turbines for the projects in conjunction with Italthai Engineering, a Thai engineering contractor. Additional financing was provided by the Bank of Ayudhya, a private Thai bank that had previously worked with EGCO and ADB.

Similarly, the Subyai project was also sponsored by EGCO (90 percent) and PVI (10 percent), which established the special purpose company Chaiyaphum Wind Farm Company Limited (CWF) to implement the project. The Bank of Ayudhya also provided additional financing.

Table 2. Key Stakeholders and Roles

Stakeholders	Roles
Electricity Generating Public Co. Ltd (EGCO)	Private power company
ProVentum International (PVI)	Private wind developer
Goldwind Science	Private wind turbine manufacturer
Italthai Engineering	Private engineering firm
Bank of Ayudhya	Private bank
Electricity Generation Authority of Thailand (EGAT)	State-owned utility
Metropolitan Electricity Authority	State-owned utility/grid operator
Provincial Electricity Authority	State-owned utility/grid operator
Energy Regulatory Commission	Government implementing agency
Agricultural Land Reform Office (ALRO)	Government implementing agency

Table 3 shows the funding breakdown for the two projects.

Table 3. Project Funding Breakdown

	Theppana	**Subyai**
CTF Concessional Financing	$4 million	$30 million
ADB Loan	$4 million	$53.15 million
Bank of Ayudhya Loan	$4.54 million	$67.90 million
Total	**$12.54 million**	**$151.05 million**

Finally, it was necessary to cooperate with the institutions that govern energy and electricity distribution in Thailand. The Electricity Generation Authority of Thailand (EGAT) serves as the country's central dispatcher and operator of the high-voltage transmissions network. EGAT generates 40–45 percent of the nation's energy, sourcing the remainder from domestic or international producers such as EGCO.[18] In 2010, the Theppana Wind Farm Company and EGAT signed a power-purchase agreement (PPA) for 6.9 MW. The PPA for Subyai agrees to 81 MW. Both agreements benefit from the adder tariff for the first 10 years. EGAT sells electricity for distribution to either the Metropolitan Electricity Authority—which serves Bangkok and neighboring areas—or the Provincial Electricity Authority. The project team also worked with the Energy Regulatory Commission and the Agricultural Land Reform Office (ALRO) to obtain the certificates and approvals necessary for construction.

Data sources

This case study uses data from extensive documentation. The IEc Team reviewed project proposals, summaries, and ADB annual review reports. The team also reviewed the CTF Investment Plan for Thailand and related communications between ADB and the United Kingdom. Other documents included articles, blog posts, and podcasts highlighting accomplishments for the CTF website and a 2018 case study on the Theppana Plant. These documents were complemented by correspondence between the evaluation team and ADB.

In addition, to estimate the health benefits of reduced air pollution resulting from a cleaner energy mix, this case study uses the Low Emissions Analysis Platform Integrated Benefits Calculator (LEAP-IBC). This model, developed by the Stockholm Environment Institute, was adapted specifically for the conditions of Thailand using data provided by the Thai Pollution Control Department. Further details are provided below in the social impacts section on health benefits.

Development Impacts from Utility-Scale Wind Power

CIF's investments in utility scale wind-power in Thailand resulted in economic, social, and market impacts. Some can be assessed quantitatively and qualitatively, while others are implied.

Economic impacts

The Theppana and Subyai projects impacted the local economies, generating a variety of direct and indirect economic DIs.

Employment gains

Both plants have provided jobs to the local community during the construction and operations phases. The process of constructing Theppana created 250 jobs, and the larger Subyai project hired 419 local workers during construction.[19] During the construction phase of Theppana, 20 percent of the jobs were held by women. Once the plants became operational, there were eight permanent positions offered at Theppana and 30 at Subyai.

These estimates do not account for any jobs created indirectly by these projects. Indirect and induced employment could result in a variety of ways. Wages from the facility employees and from farmers leasing their land to the facility are spent on goods and services in the local community, encouraging the growth of those businesses. The projects also contributed to the economic activity of the region through infrastructure investment projects. There are no data available to analyze the economic impact of these infrastructure projects (discussed below in greater detail), but they likely strengthened the economic prospects of the region and created their own job opportunities during their construction phases.

Diversified income

The Theppana project not only created economic opportunities for workers at the facilities, but also provided an additional income stream for 18 local farmers who leased land upon which the facility was constructed.[20] One farmer said she was able to earn $10,000 per RAI (a unit of area equal to about 0.4 acres) leasing her land, double the $5,000 per RAI she would earn from farming cassava. Not only did she earn more, but she was able to invest that income in fertilizer to improve the yields of her remaining cassava fields and support the education of her niece. While tracking of this benefit is isolated to this individual, it is reasonable to assume that the other 17 famers derived at least a portion of this benefit.

Market impacts

The Theppana and Subyai plants impacted the wind power market in Thailand. These impacts include market development that facilitated future utility-scale wind power projects in Thailand and progress toward meeting Thailand's goal of diversifying the country's energy mix**.** The later wind power installations facilitated by the Theppana and Subyai projects will also produce their own DIs.

Diversification of energy sources

By providing alternate sources of electricity, the development of renewable energy in Thailand provides another element to the country's energy mix. It is not a one-to-one replacement, but given that electricity demand is increasing, wind power provides energy that would have likely been filled by non-renewable sources, specifically natural gas and coal. In total, the two facilities have an installed capacity of 88.5 MW of electricity annually. Diversifying the energy mix to include more renewable energy sources provides environmental benefits by avoiding the consequences of gas-fired generation.

From 2014 to 2017, the Theppana plant operated at above 99 percent availability and generated between 12.4 and 13.8 GWh of energy, totaling 57.3 GWh over the four years. While low average annual wind speeds mean that these totals are slightly less than the original projections for electricity output, the project still has been successful at generating renewable energy for Thailand. The ADB reported that between 2017 and 2019, the Subyai plant transmitted 325 GWh.[21] This renewable electricity reduces the nation's dependence on natural gas and the associated GHG emissions. The ADB estimates that in 2021, generation from Theppana and Subyai avoided 7,152 and 69,564 tons of CO_2 emissions, respectively.

Market development

As two of the first large-scale wind power projects in Thailand, the Theppana and Subyai projects helped overcome financial and regulatory barriers to utility-scale wind energy development. The Theppana project directly paved the way for the Subyai project. Subsequently, private investors have funded additional utility-scale wind projects, increasing the installed wind power generation capacity from 630 MW in 2017 to 1,510 MW in 2020. Table 4 provides an illustrative list of select utility-scale wind projects in Thailand that followed Theppana and Subyai.

Table 4. Additional Wind Power Projects in Thailand[22]

Facility	Operational	Installed Capacity (MW)	Notes
Khao Kor Wind Farm	2016	60	Planned expansion of three 90 MW facilities
Wayu Wind Farm	2016	60	Planned expansion for five facilities with total capacity of 450 MW
West Huaybong 2 & 3 Wind Farms	2016	207	
Hadkunghan (1-3) Wind Farm	2017	126	
Hanuman Wind Farm	2019	260	Some ADB financing[23]
Total		**713**	

It is unlikely this expansion of wind power would have been possible without the CTF projects. Prior to Theppana and Subyai, private financial institutions were unwilling to support unproven wind projects with long timeframes. The CTF projects demonstrated the viability of wind power to private institutions that have funded future projects. Despite lower-than-expected energy generation at Theppana, the project was able to successfully repay its loans as scheduled. Moreover, acting as the first mover meant that the Theppana project team had to navigate a regulatory environment unfamiliar with wind technology. The time and costs the team spent working with government institutions to adapt regulations to facilitate the Theppana and Subyai projects helped minimize these barriers for future wind projects. CTF projects provided a demonstration effect, which showed private funders and developers that utility-scale wind projects are feasible and beneficial in Thailand.

Importantly, it is reasonable to assume that subsequent private utility-scale wind projects that followed the lead of Theppana and Subyai provide their own DIs, beyond the DIs that resulted directly from the CTF projects. Although some DIs may be specific to Theppana and Subyai (e.g., those stemming from specific corporate social responsibility activities, as described below under social impacts), others are expected to result from any addition of wind energy to the power mix (e.g., reduced reliance on imported fossil fuels, reduced air pollutant emissions, and improved health). These DIs are discussed in further detail below.

Capacity building

The Theppana and Subyai projects also supported market impacts by building the capacity of Thai financing and regulatory institutions. Not only did the projects build capacity for financing wind power, but they also included engagement with domestic stakeholders to increase their knowledge of and experience with wind power facilities. A case study prepared by the Global Delivery Initiative (GDI) found that CIF and ADB closed the financing gap for the projects: "The availability of debt financing with longer-than-usual tenor through a local bank, supplemented by concessional loans, played a critical role in the development and implementation" of the Theppana project.[24] This arrangement led directly to the Subyai project, which has the same ownership and financing structure. CIF and ADB financing increased the confidence of the Thai commercial bank, covered part of the capital costs, and helped mitigate first-mover risks for the bank.[25] Also, the PPA agreements with EGAT both took advantage of the adder tariff incentives for renewable energy[26] and guaranteed the purchase of electricity generated by the facilities.[27] By engaging with these domestic entities, the projects established local expertise with wind power and built the groundwork for relationships that could be used by later projects. The GDI case study emphasized that the multisector, multi-stakeholder approach—including government ministries and agencies (e.g., EGAT), private investors and developers (EGCO), private banks (Bank of Ayudhya), development finance institutions (ADB), and multilateral funding sources (CIF)— "provided the optimal mix of knowledge, financing, and risk mitigation, allowing actors to reinforce each other's expertise."[28]

Social impacts

The project plans for both the Theppana and Subyai projects included corporate social responsibility (CSR) components. These efforts have succeeded in fostering positive relationships between the plant and the local community. Reports on the Theppana project note that the community has been very welcoming of the turbines, and that there have been no associated noise complaints.[29] These CSR efforts and the resulting relationship between the facilities and local residents have resulted in several DIs.

Expanded infrastructure

To construct both wind plants, it was necessary to expand infrastructure in the region. These improvements benefit both the plants themselves and the broader community by facilitating easier travel and increased access to basic services. Specifically, the Subyai project funded road rehabilitation projects, the construction of several small dams and weirs, and the community water supply. The Subyai plant also purchased medical equipment for local hospitals, expanding their capacity to serve the community. The indirect impact of these infrastructure projects cannot be assessed with the data available, but it is expected that improved infrastructure promotes economic activity and that increased access to essential services increases the community's health and wellbeing.

Acquisition of transferable job skills

Both projects have invested in community education. Theppana has trained four plant operators, developing their skills in wind technology, and sponsored scholarships for select local students. The Subyai plant offers vocational scholarships and internships at the facility for select local students. These investments educate the next generation of renewable energy workers, increase the ability of the plants and other facilities to attract qualified workers, encourage youth to pursue careers in renewable energy, and exposes them to the benefits of wind power. Neither project established a target for the training of female workers, and the gender of those trained is unknown.

Community engagement

By fostering interactions with the local communities to each project, the CSR agendas for the Theppana and Subyai projects have increased public awareness and interest in renewable energy. Given that wind power was a relatively new concept in Thailand prior to the Theppana project, it was crucial for these projects to receive public support; public rejection of the project would have been a significant deterrent to future utility-scale wind facilities. The Theppana plant created the permanent position of community relations officer to liaise with locals, answer questions, and respond to any concerns. The plant also offers tours to school groups, which not only educate students on the benefits of wind power, but may also encourage them to pursue careers related to renewable energy. The plant is regarded as a tourist attraction by the community, and the turbines display advertisements for local businesses. At the request of local restaurants, the facility also added lights, so they can be viewed at night.[30]

The Subyai project has also sought to establish the facility as a fixture in the community. The plant has provided funding for several local construction projects including the renovation of three houses and a local temple. The plant has also supported community activities by purchasing sports equipment and sponsoring local festivals and holidays. Though the DIs are not as obvious as the economic benefits from investments in infrastructure, essential services, and job skills, fostering positive community relationships through CSR activities engenders community acceptance and encourages the development of future utility-scale wind power facilities.

Health benefits from reduced air pollutants

Displacing fossil fuel-generated electricity with wind power reduces the emissions of air pollutants, which in turn provides health benefits by reducing related illnesses and mortality. For this case study, the team modeled the health benefits of the reduced emissions as Thailand increases its share of energy from wind power according to three emission scenarios. While the impact related specifically to the saved emissions due to the Theppana and Subyai projects is relatively limited, the health benefits from significant scaling up of wind power in Thailand are substantial. Thailand's ability to meet the wind power generation necessary for these more ambitious scenarios depends on future wind power installations. As previously discussed, these projects have benefited from early CTF involvement that created a more favorable market environment, making achievement of these scenarios more likely.

Method

To quantify health impacts, the IEc Team employed the Low Emissions Analysis Platform–Integrated Benefits Calculator (LEAP-IBC). LEAP-IBC is a planning tool that can be used to assess emissions of climate-relevant GHGs, short-lived climate pollutants, and conventional air pollutants to determine how these changes in emissions impact health, climate, and agricultural outputs for a country.[31, 32] The Stockholm Environment Institute, in conjunction with the Thai Pollution Control Department, have created a version of the LEAP tool relevant to the Thai energy sector. The tool relies on time series of energy consumption data (2002–2020) provided by the Energy Policy and Planning Office within the Ministry of Energy.

The IEc Team used LEAP-IBC to characterize impacts of the following emissions scenarios:

- **Scenario 1: Ambitious renewables:** Maximum electricity generation capacity nationally (including 6,000 MW of wind energy);
- **Scenario 2: Goal-meeting renewables:** Maximum electricity generation capacity nationally (including 3,000 MW of wind energy); and
- **Scenario 3: Wind project-based:** Electricity generation capacity from the CIF-funded wind electricity generation facilities at Theppana and Subyai only.

The first ambitious renewables scenario was created based on the Renewable Energy Outlook for Thailand from the International Renewable Energy Agency (IRENA).[33] The modeling employed by IRENA aligns with Thailand's Alternative Energy Development Plan (AEDP 2015), which set a target to increase renewable energy sources to 30 percent of the country's final energy consumption by 2036.[34] This scenario is the most ambitious and includes 6,000 MW of wind-based generation.

The second goal-meeting renewables scenario was created based on the Government of Thailand's national renewable energy generation targets, inclusive of the AEDP 2015 goal to achieve 3,000 MW of installed wind power capacity by 2036. Thailand is on track to achieve this goal, as currently the wind capacity within Thailand exceeds 1,500 MW. The third scenario is for the Theppana and Subyai facilities only. From 2013 to 2015, Theppana transmitted 31.15 GWh of electricity to the national grid. From 2017 to 2019, Subyai transmitted 325 GWh of electricity to the national grid.

We compare the results of each of these scenarios with a baseline emissions scenario from the electricity generation sector for 2030, where no more renewables are added to the electricity generation system beyond what exists in 2022. We estimate changes in emissions of fine particulate matter ($PM_{2.5}$), nitrogen oxides (NOx), black carbon (BC), and organic carbon (OC). $PM_{2.5}$ and NOx are conventional air pollutants with significant impacts on human health, including cardiovascular and pulmonary diseases, hospital admissions and emergency department visits, and premature death. BC and OC are short-lived climate pollutants. Table 5 provides pollutant emission estimates for conventional and short-lived climate pollutants associated with the baseline electricity generation scenario.

Table 5. Pollutant Emissions Associated with Baseline Electricity Generation Conditions in 2030

2030 Emissions (metric tons)	Baseline Conditions
$PM_{2.5}$	7,038
NOx	228,293
BC	166
OC	795

The baseline emissions scenario is consistent with emissions projections for 2030. While the scenarios have been created in accordance with country goals for 2036, LEAP-IBC draws on emissions estimated for Thailand in 2030 due to data availability.

We estimate health impacts associated with the emissions under each scenario. Air pollution-related health impacts include disability adjusted life years (DALYs), years lived with disability (YLD), years of life lost (YLL), and premature deaths. DALYs, YLDs, and YLLs were first used by the Global Burden of Disease study to provide a broader picture of health outside of premature mortality. They are aggregate values that incorporate the impacts of a series of illnesses related to air pollution exposure. Specifically, DALYs are defined as the total number of years of life lost (YLL) due to a specific disease and the years lived with disability (YLD) due to that disease. A state of less-than-optimal health is considered to be a "disability," and one DALY represents the loss of the equivalent of one year of healthy living.

Due to the differential weighting factors applied by individual disease, DALYs can be used as a tool to compare or summarize the impacts of different diseases, including those that cause disability, but not death, and those that cause death, but little disability in advance of death. Additional information about these summary metrics is provided by the World Health Organization (WHO).[35] Table 6 includes baseline health impacts for Thailand for 2019 attributable to particulate matter air pollution exposure (ambient and household exposure). The diseases that exposure to particulate matter impacts included in the table are ischaemic heart disease, stroke, lung cancer, chronic obstructive pulmonary disease, Type II diabetes, acute lower respiratory infections, and adverse pregnancy outcomes provided by the Institute for Health Metrics and Evaluation.[36]

Table 6. Estimated Health Impacts in Thailand in 2019 Attributable to $PM_{2.5}$ Exposure[37]

Health Impact Measure	Count
DALY	1,116,134
YLD	235,993
YLL	880,141
Premature deaths	39,660

Based on these data, there are 22 years of life lost associated with each premature death and 0.27 disability life years for each year of life lost in Thailand without consideration of additional renewable energy sources in the country. We estimate $PM_{2.5}$ leads to 2,300 years of life lost in Thailand per 1,000 tons emitted, while NOx leads to 9.9 years of life lost per 1,000 tons emitted.[38]

Results

We estimate pollutant emissions associated with each electricity generation scenario using LEAP-IBC in Table 7, including baseline conditions as shown in Table 5 for comparison.

Table 7. Pollutant Emissions from each Electricity Generation Scenario

2030 Emissions (tons)	Baseline Conditions	Scenario 1: Ambitious Renewables	Scenario 2: Goal-Meeting Renewables	Scenario 3: CIF Wind Project-Based
$PM_{2.5}$	7,038	6,599	6,826	7,031
NOx	228,293	214,038	221,411	228,076
BC	166	156	161	166
OC	795	745	771	794

In Scenario 1, Ambitious Renewables, $PM_{2.5}$ concentrations decrease by 439 tons compared with the baseline, while they decrease by 212 and 7 tons in Scenarios 2 and 3, respectively. The same pattern holds for NOx. BC and OC emissions decrease only slightly in Scenarios 1 and 2, while emissions remain the same for Scenario 3. These results are consistent with our expectations. Table 8 shows our estimates of the avoided air pollution-related health impacts associated with each scenario.

Table 8. Avoided Health Impacts Associated with Air Pollution Reductions from Electricity Generation, by Scenario[39]

Pollutant	YLL, Scenario 1: Ambitious Renewables	YLL, Scenario 2: Goal-Meeting Renewables	YLL, Scenario 3: Wind Project-Based
YLLs			
$PM_{2.5}$	1,011	488	15
NOx	141	68	2
Total	1,152	556	18
Percent of 2030 Thailand YLLs			
Total	7%	3%	0%

When considering the YLL per premature death for Thailand (22 YLL per premature death), Scenario 1's 1,152 avoided years of life lost is equivalent to 52 avoided premature deaths; Scenario 2 avoids the equivalent of 25 premature deaths; and Scenario 3 avoids less than one premature death. Scenarios 1 and 2 reduce YLLs in Thailand by 7 percent and 3 percent, respectively.

To understand the economic benefits of these avoided health impacts associated with each electricity generation scenario, economists may apply the value of a statistical life (VSL). VSL is based on the willingness of a population to pay for reductions in risk. VSL can be used to provide an estimate of the costs saved due to avoided premature deaths. While VSL is an imperfect measure, we employ it in this context for cost accounting in comparison with the investments made by CIF and the Government of Thailand to increase renewable energy sources. A 2020 wage-risk study in Thailand provides mean and median VSLs of US$1.21 million and $0.66 million in 2011 USD ($1.46 million and $0.8 million in 2021 USD); a 2019 study in the *Journal for Benefit Cost Analysis* extrapolates VSL values adjusting for income differences and provides a Thai VSL of $1.29 million in 2015 international dollars.[40] We use the VSL from the Thai wage-risk study, as this method is preferable to extrapolating a US-based VSL. We provide the range of economic benefits using the median and mean VSL values for the three scenarios in Table 9.

Table 9. Benefits of Air Pollutant Emissions by Electricity Generation Scenario in 2021 US Dollars

Scenario 1: Ambitious Renewables		Scenario 2: Goal-Meeting Renewables		Scenario 3: Wind Project-Based	
Using Median VSL ($.80M)	Using Mean VSL ($1.46M)	Using Median VSL ($.80M)	Using Mean VSL ($1.46M)	Using Median VSL ($.80M)	Using Mean VSL ($1.46M)
$41.6M	$76M	$20M	$36.5M	$.80M	$1.46M

The most ambitious scenario (Scenario 1) provides benefits of $41.6–76 million, while the goal-meeting scenario (Scenario 2) provides benefits of $20–36.5 million. The wind project-based scenario (Scenario 3) provides $0.8–1.46 million in health-related savings alone.

Discussion

These three electricity generation scenarios provide insights on the health benefits of adding renewables to the system, but it is important to note that reduced air pollution and the related health benefits are not the main objective of wind power projects. At the same time, while the health benefits of the two CTF-financed projects are relatively modest, these projects have made it possible for private-sector wind developers to add significantly more capacity, and thus achieve greater benefits. Theppana and Subyai increased private sector confidence to develop wind projects, demonstrated new financing and business models, and helped catalyze subsequent wind project development in Thailand.

There are some limitations to the analysis that we performed using LEAP-IBC. As noted, LEAP-IBC provides outputs at the national scale, which assumes uniformity of changes in emissions across the country and uniformity of populations who would be exposed to those emissions. More detailed information about the location of future renewable energy sources and fossil fuel-based sources that may go offline due to inclusion of renewables will provide information to allow a more accurate spatial analysis. Furthermore, benefits calculations rely on baseline health and population data from the Global Burden of Disease study, which is an international effort that may have increased uncertainties compared with a local-scale analysis of baseline health and population across Thailand. In addition, the tool uses DALYs, YLLs, and YLDs as a measure of quality of life, which are based on a life table approach and decay functions for a suite of health morbidities. With sufficient local epidemiological information that details the relationships between air pollutant exposures and health impacts, future analyses could focus on specific health endpoints within the Thai population.

Drivers and Barriers that Affect Results

This section considers what strategies were effective in the Theppana and Subyai projects, and what barriers continue to exist for realizing the DIs of utility-scale wind power projects in Thailand.

Drivers

Two key drivers were community engagement/localization of benefits, and strengthening the regulatory environment for large-scale wind projects.

Community engagement and localization of benefits

This case study assesses many of the key impacts of the Theppana and Subyai projects, including market development and health benefits at a national level. The substantial footprint of these DIs is one of the strengths of these projects; while wind conditions are only suitable for utility-scale wind power in a small portion of Thailand, the entire Thai population can benefit from these facilities. However, for equity reasons and to engender community acceptance, it is also important to ensure that benefits accrue to the local population where the turbines are sited.

The Theppana and Subyai projects were well designed to ensure that certain DIs targeted local communities and community members had meaningful engagement with the project developers. Most significantly, the economic impacts of employment gains and diversified incomes were concentrated in the local communities. Rather than importing qualified workers from other parts of Thailand or from abroad, the developers trained local people for the jobs. They also sponsored scholarships for students. The Theppana project trained four plant operators, and the Subyai plant offered internships. These strategies not only created a pipeline of qualified workers, but also benefited the local community.

While the economic opportunities are the most significant, the benefits of each facility's CSR agenda also accrued at the local level. These agendas funded community-driven projects, including infrastructure projects that increased access to economic opportunities and essential services. Engagement activities such as school tours and internships raised awareness of wind power and renewable energy resources. The Theppana project strengthened ties between the facility and local population through activities such as advertising for local businesses on the turbines and stringing lights at the request of local restaurants.

The accumulated impact of these locally accruing benefits was significant for generating local support. With this support, the projects were able to demonstrate that not only is utility-scale wind financially viable, but it is also beneficial for local communities. The success of the Theppana and Subyai projects—on their own and as demonstration projects—likely would not have been possible if the communities living near the Theppana and Subyai plants had rejected the installations. Instead, the plants grew the capacity of local communities, provided economic opportunities, and supported community projects, and the turbines have become accepted and celebrated features.

Strengthening the regulatory environment for large-scale wind projects

The projects were also crucial to overcoming the regulatory barriers to renewable energy projects. Earlier attempts to develop wind power had faced significant delays in the permitting process, as Thai regulations were not designed for renewable energy sites. As Thai certifying institutions were largely unfamiliar with wind technology, ADB both acted as mediator and provided technical expertise in the dialogues between the project team and inspectors. These conversations resulted in regulations better adapted to and more favorable for wind power. For example, a major change was exempting wind power projects from safety regulations for tall buildings; construction licenses for tall projects had requirements for escape routes that were suitable for buildings, but not turbines. ADB was key in negotiations between the project team and certifying institutions to waive and adapt regulations. These improvements to the regulatory environment also facilitated later wind projects by reducing the barriers and therefore increasing the interest of potential partners and investors.

Barriers

The strategies employed by CTF reduced the market and regulatory barriers to utility-scale wind power in Thailand. However, wind remains an emerging technology with high upfront costs and risks inherent in major infrastructure investments. Moreover, since the Theppana and Subyai projects, land use concerns have emerged as an issue for wind power development. There are few regions in Thailand with wind speeds sufficient to establish generating facilities, so developers are limited in project site options. The Theppana project did not encounter any land use issues, as it leased land from local farmers with approval from the Agricultural Land Reform Office (ALRO), which manages land designated for agricultural purposes. However, the Subyai plant has faced ongoing issues related to land use. In 2017, the Supreme Administrative Court ruled that the facility could not lease ALRO-owned land designated only for farming purposes. This ruling impacted existing and future wind power plants. To resolve the issue, the government ruled that any companies with existing PPAs with EGAT could resume their operations on ALRO land. New projects are being considered on a case-by-case basis. This uncertainty related to land access may deter future wind power installations. It also underscores the need to strike a thoughtful balance between new wind energy development and traditional land uses. Designing projects to localize DIs and compensating host communities for any adverse impacts may be necessary to strike an appropriate balance.

CIF and MDB Contributions to DIs

CTF support was essential for the expansion of wind energy in Thailand, supporting first-mover projects and creating an enabling environment for later privately funded projects to succeed. Prior to the Theppana project, there was interest in developing wind power projects in Thailand, but regulatory and financing barriers prevented utility-scale projects. Financial institutions in Thailand were unwilling to extend 20–25-year loans to support wind power given the relatively low wind speeds in Thailand. Concessionary financing allowed for a higher risk appetite for the Theppana project and filled the financing gap, demonstrating the viability of utility-scale wind power projects in Thailand. Theppana's success translated directly into the larger Subyai project, which further showcased the potential for wind technology. Both projects have the same ownership and financing structure, based on the partnership between ADB and a local commercial bank.[41] By demonstrating a viable approach for private sector involvement in large-scale wind projects, Theppana and Subyai paved the way for financing for future wind projects. Since the completion of the Subyai plant, there have been several other utility-scale wind power plants constructed in Thailand without any concessional financing, as summarized in Table 4 above.

As of 2017, a total of 630 MW of wind power was installed in Thailand, and projects in development were projected to bring the total capacity to 1,600 MW. By 2020, 1,510 MW were installed. These projects are expected to produce similar benefits for the country and local community as the Theppana and Subyai projects, including diversifying the country's energy mix, providing new economic opportunities, and improving health outcomes. While CTF was not directly involved with these projects, it is unlikely they would have occurred without the first movers of Theppana and Subyai demonstrating the financial viability and reshaping the regulatory environment.

Future Opportunities: Lessons for CIF and Other Climate Funders

Measuring and increasing gender-related benefits

Gender-related benefits from CTF investments in utility-scale wind in Thailand are implied, but difficult to assess. The Theppana facility noted the share of women employed during construction, but any other benefits accruing specifically to women were not tracked or reported. To increase women's participation in these facilities and future projects beyond 20 percent of temporary positions, projects should set more ambitious targets and direct DIs specifically towards women. Research suggests women are likelier than men to spend additional income on education and income-generating activities for their families.[42] The anecdote about the woman farmer who leased land to the Theppana facility and used the additional income to support her farm and her niece's education is one example of the follow-on DIs that can result from increasing women's incomes. The existing information implies 1) there may be untracked gender-related benefits that accrued under the Theppana and Subyai projects, and 2) DIs might have been even more significant if gender benefits were more actively targeted by the projects.

Future projects targeting utility-scale renewable energy should take steps to expand gender-related benefits. First, planners should target women's participation during project design. Projects may want to consider directing employment or skills development specifically for female workers. Projects could also consider designating some CSR funds specifically for women. Second, project managers should track gender-related benefits during the project monitoring phase. Improved tracking can identify what gender-related benefits occur, as well as any potential barriers to achieving gender-related benefits. Projects can then take steps to address these barriers to further increase female participation and gender-related DIs.

Potential for scaling and replication

The Theppana and Subyai projects have already facilitated several private, utility-scale wind power projects in Thailand. By acting as first-mover projects they reduced barriers related to regulations and financing availability for subsequent projects. CTF and ADB backing increased the private sector's appetite for large-scale wind projects and strengthened the position of the project team in conversations with regulatory institutions. This model of supporting first-mover projects to improve the market for private financers could be applied in a variety of contexts, including other large-scale renewable energy projects or other country contexts where the availability of financing is limited. CTF has used similar techniques to support solar power development in Thailand.

Thailand's increased commitment to renewable energy has also led to the adoption of additional technologies to increase the efficiency of utility-scale wind power. For example, in 2020 the first battery storage system was installed at a wind power plant in Southern Thailand. The introduction of battery technology speaks to the increase in the country's generating capacity in recent years, while also demonstrating additional opportunities for expanding the role of wind power.[43] The ability to stockpile excess wind power will create more consistency, given the variability of Thai wind speeds, and perhaps expand the benefits of wind power even to communities without suitable conditions for wind facilities.

Endnotes

[1] GDP data (in current US dollars) are from the World Bank: https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=KH-LA-MM-MY-TH-BN-SG-ID-PH-VN. Population and urbanization data are from the United Nations. See:
UN DESA (2022). World Population Prospects 2022. New York: United Nations Department of Economic and Social Affairs, Population Division. http://esa.un.org/unpd/wpp/.
UN DESA (2018). World Urbanization Prospects 2018. New York: United Nations Department of Economic and Social Affairs, Population Division. http://esa.un.org/unpd/wup/.

[2] CTF Private Sector Proposal: Thailand Renewable Energy Accelerator Program. Climate Investment Funds.

[3] See the International Energy Agency (IEA) profile page for Thailand: https://www.iea.org/countries/thailand.

[4] CTF Private Sector Proposal: Thailand Renewable Energy Accelerator Program.

[5] See historical GHG emissions data (including LUCF) on Climate Watch: https://www.climatewatchdata.org/ghg-emissions.

[6] Van Den Akker, Jan. 2018. Theppana Wind Power Project, Thailand: Pioneering Private Sector Utility-Scale Wind Power. Climate Investment Funds.

[7] CTF Private Sector Proposal: Thailand Renewable Energy Accelerator Program.

[8] The Thailand Integrated Energy Blueprint combined five industry specific strategies: the Power Development Plan, Alternative Energy Development Plan, Energy Efficiency Plan, Oil Plan, and Gas Plan.

[9] See IRENA country profile for Thailand (last updated August 2022): https://www.irena.org/-/media/Files/IRENA/Agency/Statistics/Statistical_Profiles/Asia/Thailand_Asia_RE_SP.pdf.
[10] Van Den Akker, Jan. 2018. Theppana Wind Power Project, Thailand: Pioneering Private Sector Utility-Scale Wind Power.
[11] Thailand. Asia Wind Energy Association. https://www.asiawind.org/research-data/market-overview/thailand/.
[12] Small power producers operate projects generating between 10 and 90 MWs of electricity. Very small power producers are projects up to 10 MW.
[13] The program was eventually revised to include a competitive bidding scheme, first in 2015 for VSPPs and then in 2017 for SPPs. This change refocused the program on the most cost-effective projects to address concerns about over-subsidizing and uncertainty in the tariff calculation methods.
[14] The Plan was updated in 2012.
[15] Clean Technology Fund Update of Investment Plan for Thailand Draft. 2011, September. Ministry of Finance.
[16] Though CTF also funded other renewable energy projects, particularly solar, these projects are outside the scope of this case study.
[17] Van Den Akker, Jan. 2018. Theppana Wind Power Project, Thailand: Pioneering Private Sector Utility-Scale Wind Power. Climate Investment Fund.
[18] Van Den Akker, 2018.
[19] Van Den Akker, 2018.
[20] Duarte, Mafalda. 2018. Thailand, On a Fast Track to a Low Carbon Economy. Climate Investment Funds. https://www.climateinvestmentfunds.org/cif_enc/news/thailand-fast-track-low-carbon-economy.
[21] Extended Annual Review Report for the Subyai Wind Power Project. 2020. Asian Development Bank.
[22] Van Den Akker, Jan. 2018. Theppana Wind Power Project, Thailand: Pioneering Private Sector Utility-Scale Wind Power.
[23] NS Energy Staff Writer. 2019, October 18. ADB to Invest $98.7m in Energy Absolute's Hanuman Wind Farm in Thailand. NS Energy. https://www.nsenergybusiness.com/news/adb-hanuman-wind-farm-thailand/.
[24] Van Den Akker, Jan. 2018. Theppana Wind Power Project, Thailand: Pioneering Private Sector Utility-Scale Wind Power. The longer tenor of financing can help renewable energy project sponsors spread the costs of repayment over a longer period, improving annual cash flows. Commercial banks were previously reluctant to provide long-tenor financing for wind projects given uncertainty about annual energy production and sales.
[25] Van Den Akker, 2018.
[26] The adder feed-in tariff for renewables is a premium on top of the wholesale electricity price, guaranteed for a period of 7-10 years. In 2015, the adder tariff was replaced by a new Feed-In Tariff. Van Den Akker, 2018.
[27] Both projects have PPAs at the wholesale tariff and applicable adder of USD 0.11 (THB 3.5) per kWh adder for 10 years from the commercial operations date. After 10 years the tariff will revert to the wholesale tariff level. Van Den Akker, 2018.
[28] Van Den Akker, 2018.
[29] Van Den Akker, 2018.
[30] Van Den Akker, 2018.
[31] Low Emissions Analysis Platform – Integrated Benefits Calculator (LEAP-IBC) Fact Sheet. Stockholm Environment Institute. https://mediamanager.sei.org/documents/Publications/SEI-Factsheet-LEAP-IBC-2.pdf Accessed February 2022.
[32] While LEAP-IBC can analyze the impacts of pollution on agricultural outputs for some countries, this function is not currently available for Thailand.
[33] IRENA (2017). Renewable Energy Outlook: Thailand, International Renewable Energy Agency, Abu Dhabi.
[34] IRENA's analysis indicates that Thailand has the potential to increase the share of renewable energy to 37%, exceeding the goal of 30%.
[35] World Health Organization. 2013, November. WHO methods and data sources for global burden of disease estimates 2000–2011. https://www.who.int/healthinfo/statistics/GlobalDALYmethods_2000_2011.pdf?ua=1 Accessed February 2022. ADB
[36] The most recent health data available are from 2019.
[37] Institute for Health Metrics and Evaluation. 2022. Global Health Data Exchange. http://ghdx.healthdata.org/gbd-results-tool Accessed February 2022.
[38] Van Zelm R, Preiss P, van Goethem T, Van Dingenen R, Huijbregts M. 2016. Regionalized life cycle impact assessment of air pollution on the global scale: Damage to human and health vegetation. *Atmospheric Environment* 134 (129-137). https://www.sciencedirect.com/science/article/pii/S1352231016302084
[39] Values may not sum due to rounding.
[40] Witvorapong N and Komonpaisarn T. 2020. The Value of a Statistical Life in Thailand: Evidence from the Labour Market. *Journal of Consumer Policy* 43: 491-518.
Robinson, L., Hammitt, J., & O'Keeffe, L. 2019. Valuing Mortality Risk Reductions in Global Benefit-Cost Analysis. *Journal of Benefit-Cost Analysis* 10(S1), 15-50. doi:10.1017/bca.2018.26

[41] Van Den Akker, 2018.

[42] Relevant research includes: Duflo, E. 2003. Grandmothers and Granddaughters: Old-Age Pensions and Intrahousehold Allocations in South Africa. *The World Bank Economic Review* 17(1):1-25. DOI: 10.1093/wber/lhg013; Thomas, D. 1990. "Intrahousehold Resource Allocation: An Inferential Approach. *Journal of Human Resources* 25(4): 635-664; and Thomas, D. 1994. Like Father, Like Son, Like Mother, Like Daughter: Parental Education and Child Health. *Journal of Human Resources* 29(9): 50-88.

[43] 2021. Thailand Stores up on Green Power with Cutting-Edge Battery Systems. Climate Investment Funds.

13. Türkiye Light-Touch Case Study: Scaling up Renewable Energy and Energy Efficiency Projects

Project Details	Funding
Name: Private Sector Renewable Energy & Energy Efficiency Project **Country:** Türkiye **CIF Program Area:** Clean Technology Fund (CTF) **Bank approval:** May 2009 **Effective since:** June 2009 **Project close:** December 31, 2016 **MDB:** World Bank	**Total Cost:** $3,099.56 million **MDB:** $950.66 million **CIF:** $100 million **Co-financing (donors and sponsor equity from FIs):** $2,048.9 million **Instrument type:** Loan **Sector:** Private

Key Highlights

- CIF's Clean Technology Fund (CTF) and the World Bank have provided US$1.051 billion to finance renewable energy and energy efficiency investments via two credit lines for two Turkish development banks.
- This case study focuses on the development impacts of CIF's Renewable Energy and Energy Efficiency Projects, which were funded by this budget.

Topline Findings on Development Impacts

- **Market development:** The project helped remove a key barrier to renewable energy investments in the country: the limited availability of financing for capital-intensive energy sector projects. The World Bank and CTF loans made it possible to grow previously underdeveloped energy efficiency markets and financing strategies. The two participating financial institutions have also set up dedicated energy efficiency departments.
- **Reduction of GHG emissions and air pollutants:** GHG emission reduction outcomes from energy efficiency exceeded targets (102 percent), while those from renewable energy reached 84 percent, as the benefits from the largest geothermal power plant funded were smaller than projected.
- **Other DIs:** Additional benefits include local job creation and health benefits from improved local air quality, and increased gender equality through new job opportunities and improved access to essential services.

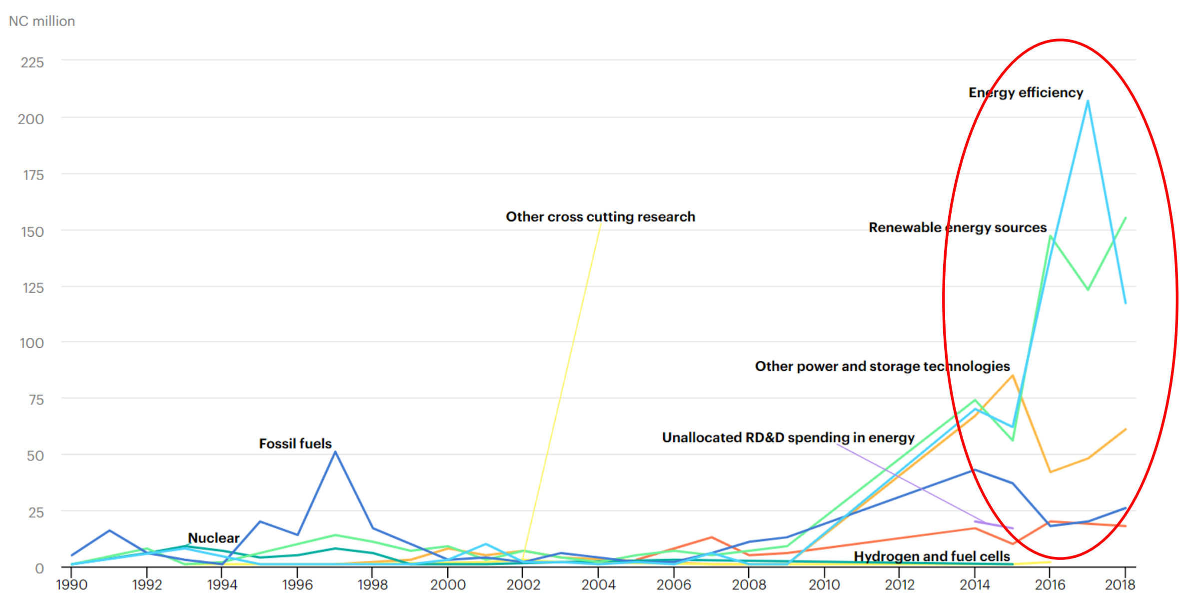
Climate Investment Context and Overview

Türkiye's rapid economic growth has driven up energy demand, and the government has responded by significantly expanding and diversifying the energy supply. From 2010 to 2021, renewable electricity generation doubled, reflecting more than tenfold growth in geothermal and wind generation and the rise of solar photovoltaics (PV) as a major energy source.[1] However, because energy demand has risen so fast, requiring a nearly 50 percent increase in the total energy supply from 2010 to 2021, Türkiye remains highly dependent on (mostly imported) fossil fuels. Coal, oil, and natural gas made up nearly 84 percent of

Türkiye's energy mix and accounted for 64 percent of power generation in 2021—down from 89 and nearly 74 percent, respectively, in 2010, but still a large share.

As shown in Figure 1, Türkiye's budget for research, development, and innovation (RD&I) in renewable energy technologies and energy efficiency has grown sharply since 2008. Indeed, those were the top two fields supported by the Turkish government in its 2018 RD&I budget, with 72 percent of total funding.[2] This reflects political priorities to increase the share of domestic renewable energy sources (RES) and decrease imports, as well as the passage of the Energy Efficiency Law in 2007, though investment in energy efficiency RD&I fell significantly between 2017 and 2018.

Figure 1. RD&I Budget per Technology Group in National Currency, Türkiye 1990–2018



Data source: International Energy Agency (IEA).

In 2009, the Climate Investment Funds (CIF) supported investments in power generation from renewable sources—including small hydro, wind, geothermal, solar, and biomass—and energy efficiency to help investors and companies benefit from Türkiye's clean energy revolution while growing the electricity supply to meet demand. With the funds provided by the World Bank and CIF, the Turkish development banks supported emerging energy markets and small-scale renewable energy projects and built knowledge and capacity in the RES sector. Concessional finance helped lower the perceived risks of investing in energy efficiency and RES projects, and technical assistance was provided to increase awareness within small businesses and commercial retail banks about the profitability of the emerging technologies in the sector.

All this has helped Türkiye advance its renewable energy and efficiency goals, but more remains to be done. The country's Eleventh Development Plan (2019–2023) set a target of at least 38.8 percent of power generation from renewables, which it exceeded in 2019 and 2020, but missed in 2021 due to low hydropower production.[3] Türkiye has been less successful in achieving the target of the National Energy Efficiency Action Plan (NEEAP), covering 2017–2023, to reduce primary energy consumption by 14 percent from business-as-usual levels across several sectors.

The COVID-19 pandemic has also created new challenges. After an initial economic rebound, macroeconomic financial uncertainties are expected to arise.[4] Inflation remains above the official target and the pandemic has exacerbated structural challenges related to high unemployment and low labor force participation. However, reducing GHG emissions and curbing air pollution are pressing issues that require intervention. Türkiye's GHG emissions increased faster than those of any other member of the Organisation for Economic Co-operation and Development (OECD) in the past decade.[5]

Based on a desk review and interviews, this light-touch case study examines the development impacts (DIs) of the CIF/World Bank project, which ran from 2009 to 2016. As noted, the funds were channeled through two Turkish development banks (TSKB and TKB) via two credit lines. Due to non-disclosure agreements between borrowers and their customers, it was not possible to retrieve investment and impact data at the subproject level on the banks' onward investments. The beneficiaries of the loans and equity participation provided by the Turkish development banks were private companies (small and medium-size enterprises, smallholder farmers, and industrial stakeholders) whose economic conditions and profitability have improved thanks to the concessional finance provided. [6]

Project stakeholders

The main stakeholders include the two largest state development banks in Türkiye, the Turkish Industrial Development Bank/Türkiye Sınai Kalkınma Bankası A.Ş. (TSKB) and the Turkish Development Bank/Türkiye Kalkınma Bankası A.Ş. (TKB), as well as IBRD and other multilateral development banks supporting the planned investments: the European Bank for Reconstruction and Development (EBRD) and the International Finance Corporation (IFC).

Project objectives related to CIF financing

The project aimed to (1) increase privately owned and operated energy production from domestic renewable sources, with a focus on small-scale renewable energy projects and with innovative RES technologies, within the market-based framework of the Turkish Electricity Market Law; (2) enhance energy efficiency; and (3) thereby help reduce GHG emissions. The project therefore supported, through the borrowers, smaller-scale RES projects, in three categories, as detailed in Table 1. In addition, technical assistance was provided with support from other entities, including bilateral donors and the United Nations Development Programme.

Table 18. Project Categories

Category	Description	CTF contribution
Commercial-scale RES	• Hydropower projects exceeding 10 MW capacity	• N/A
Emerging RES	• Emerging renewable energy technologies, including solar, biomass, geothermal, wind and small-scale hydro (less than 10 MW)	• The CTF funds went to projects in these emerging technologies and in energy efficiency, covering 15–20% of project investment costs. The CTF allocation was used to pull in new investors and mitigate regulatory gaps that prevented

Category	Description	CTF contribution
		their applicability to smaller generation units.
Energy efficiency	• Subprojects to achieve at least a 20% reduction in energy consumption, or 50% cost savings from reduced energy use. Demand-side measures, mostly in the cement, chemicals, and steel sectors.	• CTF funds covered 15–20% of project investment costs (see above).
Other technical assistance	• Technical assistance (TA) financed by other donors, provided in parallel with RES and energy efficiency investments, intended for capacity building among banks and industry to help reduce the barriers to energy efficiency investments.	• N/A

At the appraisal stage, the project initially dedicated US$500 million of IBRD resources and US$100 million of CTF resources toward the credit lines, supported by a parallel technical assistance program financed by other donors that focused on building energy efficiency expertise within local financial institutions for carrying out due diligence assessments and providing advisory services. It had a single-component design, with two credit lines, that was maintained until closure. (In contrast, other projects have multiple components, which often separate financing from TA; for example, see the India light touch case study.) It was restructured IBRD in September 2011 and received additional financing of US$500 million. Restructuring was needed to address safeguards and compliance issues with small-scale hydropower projects, and because investments in small-scale hydropower in particular had become more attractive to private investors during project implementation. Small hydro projects were reclassified as commercial RES rather than emerging RES due to their commercial viability, and this made them ineligible for CTF funding. The additional financing reprioritized non-hydro emerging RES and energy efficiency through a limit on funding for commercial RES and a clarification of eligibility criteria for energy efficiency.

The final total project cost was estimated at US$3.1 billion (adding up to 269 percent of the estimated costs at appraisal). This increase is partly explained by the additional funding provided by the IBRD and other donors, but it is mainly due to the increased appetite of borrowers in taking larger equity participation in the financial structuring of the small-scale RES projects because of the expected high returns, such that the concessional financing components became relatively smaller over time.[7]

The project strategy targeting small-scale RES and energy efficiency projects through credit lines via the Turkish development banks, who are trusted partners of IBRD with strong in-country networks and established project pipelines, was deemed to have been very successful by the IBRD's task team leaders for addressing the long-term financing constraints of SMEs for developing small-scale projects. The timing of the project intervention was also relevant, given Türkiye's urgent need at the time for energy efficiency investments and the securing of domestic energy supply.

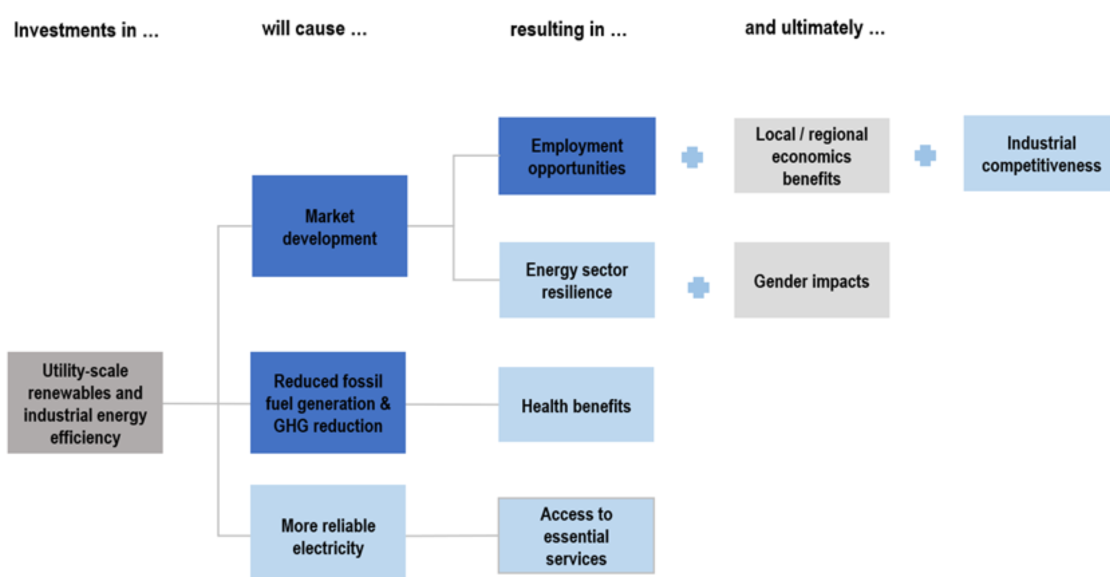
Development Impact Pathways and Case Study Focus

An impact pathway for the investments is presented in Figure 1. The project's various DIs are primarily driven by the accelerated market development in RES, increased energy efficiency, and a slower increase in fossil fuel-based generation as a result. The project documents—notably the Project Appraisal Document (PAD) and the Implementation Completion Report (ICR)—compile some of these results, while others were documented based on stakeholder interviews.

This light-touch case study focuses on the DIs that the evaluation team identified as the most relevant considering the inputs provided by stakeholders. The **dark blue boxes** indicate the DIs quantitatively addressed in this case study: market development, reduced fossil fuel generation and employment opportunities. The **light blue boxes** indicate the DIs qualitatively addressed in this case study: health benefits, more reliable electricity, energy sector resilience, access to essential services, and industrial competitiveness. The **gray boxes** indicate DIs that should follow from the investments but are either too long-term to assess currently and/or would require additional research and analysis to address. Specifically:

- Local and regional economic benefits are hard to quantify, but stakeholders outlined some examples where the investments had a direct effect on surrounding locals.
- Gender-related impacts have (unintendedly) occurred in at least one instance, based on stakeholder interviews, but more evidence could not be retrieved on these.

Figure 19 Impact Pathways of Energy Efficiency and RES Development



Development Impacts: Performance to Date (Quantitatively Assessed)

Market development

The project helped remove existing barriers to renewable energy investments in the country, namely the limited availability of financing for capital-intensive energy sector projects.[8] The World Bank and CIF loans made it possible to grow previously underdeveloped energy efficiency (EE) markets and financing strategies involving the two Turkish development banks. These Turkish financial institutions also set up dedicated energy efficiency departments to carry out due diligence assessments of projects and provide advisory services to their clients.[9] At the start, in the absence of an energy efficiency market and lack of good enforcement of energy efficiency standards, the project was unable to spend the dedicated EE funds. The banks did not have experience with EE lending, and there were no qualified companies to do it. Despite these challenges, the project helped establish the market. The sector has gained valuable practice and examples in the field, and the continued private sector investments into the supported technologies will help sustain growth and raise living standards while creating new employment opportunities in the future.

The ICR tracks the leveraged finance and the amounts disbursed as loan funds. The cost effectiveness of CTF funding in particular was high: the US$100 million leveraged $898 million from other international financial institutions, well above the $400 million estimated at appraisal. TKB was able to commit 95 percent of its loan funds and disburse 90 percent, while TSKB was able to commit and disburse 100 percent of its loan funds. The percentage of RES and EE projects in their portfolios significantly exceeded target values, mostly on account of the change in priorities expressed during the restructuring of the project.

Increased renewable energy production and GHG emission reductions

Most of the quantifiable results in the PAD were framed in terms of the increase in both capacity and production of RES from the various sources supported, and in the share of RES to total generation. The planned outcomes were mostly achieved and, in some cases, exceeded: for non-hydro RES plants, the capacity added was 163 percent of the target, reflecting the switch in priorities after small-scale hydro financing was stopped.[10] GHG emission reduction outcomes from energy efficiency also exceeded target values (102 percent), while those from RES reached 84 percent because of a mismatch in expected and actual reductions in the largest geothermal power plant that was funded.

Employment opportunities

While no data are currently available on the exact number of jobs created, among the social impacts recorded in the PAD, it is noted that significant direct and indirect job creation was achieved among principal stakeholders in the project (financial institutions), their contractors and suppliers of related machinery, and people employed during construction, operation, and maintenance of the facilities. Job creation was particularly high during implementation of energy efficiency measures, and also especially in hydro projects during their construction, but the project also created permanent jobs in the wider industry. These economic benefits are localized, with Turkish companies carrying out a major part of the construction. Most new hydroelectric plants and the associated jobs are in the poorer mountainous and rugged areas of the country.

Table 2. Summary of Quantified DI Benefits Assessed

DI	Included in original project documents?	Metric /KPI	Method of assessment
Market development	Yes	Amount spent on new RES and energy efficiency, banks continuing to finance projects	Estimation included in the project documentation
Reduced fossil fuel generation	Yes	MWs of RES deployed	Estimation included in the project documentation
GHG reduction	To some extent	Target values for supported technologies, carbon savings based on emission factors	Estimation included in the project documentation and impact assessment[11]
Employment opportunities	To some extent in PCR	N/A	N/A

Other DI Benefits (Qualitatively Assessed)

Health benefits from reduced air pollution

As the project reduced emissions by reducing demand for electricity from fossil fuel sources (by providing clean power from RES and reducing energy use through energy efficiency investments), non-negligible health benefits are assumed to have occurred. With less power generation from fossil fuels, especially coal, there would be less associated air pollution and lower pollution-related morbidity and mortality rates.[12]

Emissions were also reduced by energy efficiency measures. These improvements cascaded into industry. Once the most emissions-intensive industries (steel, cement, chemicals) had carried out energy efficiency improvements, other industries followed suit, impacting the industrial sustainability approach in Türkiye. Unrelated to the current project, the Turkish government has enacted strict environmental limits on coal plants. Thermal power plants are subject to the Industrial Air Pollution Control Regulation, setting limit values for air pollutants such as SO_2, CO, NOx.[13] These and other industrial emission standards have been in place since 2009 and are updated frequently.[14]

Local and regional economic benefits

The project has resulted in new forms of economic activities that benefit the local population directly. For example, one geothermal project had significant unplanned positive DIs, combining circular economy principles with benefits for women. The project incentivized a tomato farmer to create a closed loop of resources, using the residual heat coming from a local geothermal district heating plant for operations on his farm. Due to the expanded farming activities, he was able to employ all the women from the local village. The related incomes enabled the women to send their children to school and enhanced their financial situation. In another instance, a farmer translated the energy generation into stable cash flows (via feed-in-tariffs) after learning about energy trading.

Energy sector resilience, more reliable electricity, and access to essential services

Well-targeted investments in energy efficiency and decentralized renewable generation have been shown to enhance the capacity and reliability of energy systems, making them more resilient to internal and external shocks, while reducing import dependency. Energy efficiency and RES investments reduce electricity demand and increase supply in parallel, enabling suppliers to broaden their consumer base and meet increasing energy demand. Reliable electricity supply was a challenge at that time in Türkiye,[15] even though it is essential for residents and businesses as well as public institutions (such as healthcare centers and schools) and can lead to improved quality of life.

Industrial competitiveness due to energy efficiency improvements

At the start of the project, Turkish industry accounted for about 32 percent of final energy demand, so the sector was prioritized for energy efficiency efforts. Energy-intensive industries such as cement, iron, and steel needed a way to reduce their energy consumption to stay competitive. In addition, the textile and paper industries were also significant energy users. It is reasonable to assume that the considerable energy savings from adopting energy efficiency measures paid off within a few years and made Turkish industry more competitive in the long term.

Other Implied DI Benefits (Not Assessed)

Other potential impacts were identified through stakeholder interviews. These were not comprehensively researched as part of this light-touch case study. They include:

Capacity building and education: Due to emerging renewable energy and energy efficiency markets attracting new talent to the sector, universities opened energy management and RES finance departments that are now able to educate the sector's future workforce.

Competitiveness of the advisory sector: The consultancies and service providers involved in the project that were subject to World Bank requirements have increased the quality of their services. On the energy efficiency side, the project improved the efficiency and competitiveness of the participating companies.

Engagement with local communities resulting in wider societal acceptance of RES: An interview related to one of the geothermal projects identified localized social benefits from engagement with communities. Initially the local community was resistant to the plant, as they did not perceive any benefits from the project. The project team reached an agreement with the plant owners to provide financial support to local students and sponsor several local events and activities. Later they also provided warm water for public use. These engagements created much broader acceptance of the project and good relationships with locals separate from the development finance provided.

Increased financial and energy literacy: One of the task team leaders described engagement with local residents as effective in cases where individuals had no prior knowledge about the benefits of small-scale renewable energy. In locations where most residents have occupations unrelated to renewable energy (e.g., peanut farmers and textile manufacturers), people had to be educated about the advantages of local generation and guided in installing these technologies. For a peanut farmer who previously did not care about the financial benefits of small-scale renewables, describing the potential for cash flow (e.g., via feed-in-tariffs) was helpful. The market thus presented small business owners with opportunities to consider how the various aspects of energy trading could maximize their profits. The concept of energy efficiency first had to be introduced and translated, but it brought promising cost savings and developed capacity.

Negative environmental impacts

There were accounts of unintended negative impacts. Previous task team leaders reported that due to significant volumes of capital going toward small-scale hydro, cascading mini-hydroelectric plants were built in places where they proved detrimental to the river flows, fish populations, and surrounding vegetation. The change in water level also had social impacts, mostly on surrounding communities who used the water sources for drinking and fishing. These impacts were later addressed by looking closely at regulations with the relevant ministries to minimize the impacts of small-scale hydro. The IBRD consulted environmental experts and analyzed the cumulative impacts and proposed new regulations for river basin management. IBRD's team also held workshops and consultations for developers and construction companies who were inexperienced in these types of projects.

Enabling Conditions for DIs

Government support/policy environment and guarantee mechanisms

The Implementation Completion Report (ICR) states that the Turkish government showed significant commitment to the project,[16] and at the time of the ICR was implementing various legislative measures to promote private investment in RES and energy efficiency. For renewable energy, these included a feed-in tariff scheme, land usage fee incentives for generation facilities, permitting up to 1 MW generation facilities without requiring a license, and a purchase obligation for electricity from renewable sources. These policies helped reduce risk to investors. For energy efficiency, the Energy Efficiency Law of 2007 and its two Bylaws of 2008 required industry to report on their energy management activities to the Ministry of Energy and Natural Resources and introduced an obligation to set up an energy management unit in these facilities. These requirements all helped raise awareness of the potential for energy efficiency in industry and positively impacted energy efficiency-related investments.

Close cooperation with the Turkish government as well as open discussions on the topics of energy policy, renewable energy and energy efficiency were also key to making progress in the project. The transmission system operators (TSOs) and the government were not confident that the grid could handle intermittent renewables and initially took a conservative approach to these new sources. Once they saw issue-free implementation, they became confident that RES and energy efficiency were viable in Türkiye.

Financial concept

The task team leaders noted that the main lesson learned and success of the project centers around the project design concept to provide a concessional FI loan (via credit lines) to trusted local development partners, with a strong local network and reputation and established client portfolios in the Turkish market, which then provide small-scale loans to their customers on fully commercial terms. In this specific context, the financial concept provided a way to support small-scale RES and EE projects at a time of increased momentum, combined with strong policy and regulatory support. The IBRD has considered using the same financial model for small-scale RES and EE in other developing countries with a similar context.

The model allowed for targeting different segments of the market and created a healthy competition between the financial intermediary banks. Similar effects could also be achieved through an apex bank model with several participating financial institutions.[17] Conceptually, the concept was a good fit for the target investments, as small-scale loans are typically not provided directly by the IBRD due to their limited impact and capital size at the subproject level relative to transaction and project management costs. The resulting capital cost buy-down has proven to drive down costs for the final beneficiaries.

Timing and flexibility

The right timing was essential for success. There was an ongoing energy supply security problem in Türkiye while the project was prepared. However, climate change policies were already in place—for instance, feed-in-tariffs were already established instruments, creating a good starting point for mobilizing finance. The fact that RES costs started to come down globally was another key reason why the initial targets were achieved and exceeded. Furthermore, the project demonstrated flexibility by restructuring to focus donor resources on emerging (less commercial) opportunities that arose during implementation.

Barriers to Project Implementation and Realizing DIs

The main barriers that hindered the realization of DIs throughout the project are described below, and were identified based mostly on stakeholder interviews:

Institutional capacity/awareness and commercial barriers

Commercial banks' lack of familiarity with financing energy efficiency projects, and SMEs' lack of awareness of the benefits of energy efficiency investments, made it difficult to translate the intended benefits into attractive opportunities at the start of the project. According to stakeholders, even the largest developer in Türkiye at the time could not meet the safeguarding rules for building the renewable energy assets, which made it significantly challenging to kick off financing in the first year of the project. These issues were often related to the needed infrastructure (e.g., access roads) to build the power plants, which fell under different regulations than the plants themselves. The IBRD had to propose new rules (e.g., to avoid soil erosion due to informal roads) in the market that were later adopted by the government and forced the sector to scale up and improve its approaches.

Regulatory and project evaluation-related barriers

Private investments in hydropower became more attractive during project implementation. Thus, during restructuring, small hydropower projects were reclassified and made ineligible for CTF funding.[18] This change was also partly due to the realization that safety and environmental rules were not being followed to the desired standards when building small hydro plants. Better planning, precautionary regulatory measures, and capacity building on safeguards for developers would have been necessary to avoid the negative environmental impacts to waterbodies and surrounding ecosystems. Going forward, non-disclosure agreements with project beneficiaries should be written in such a way that they allow funders to gather necessary (anonymized as necessary) data in order to monitor DIs and facilitate evaluation.

There were other barriers to realizing DIs such as gender equality and improved employment opportunities as well. Interviewees mentioned that the climate impacts of these types of projects are prioritized and pushed for evaluation, but there is a need to broaden the scope and look at other impacts as well. Most projects (especially those that started 10–15 years ago) were not designed with a gender component in mind, and gender considerations are not given in-depth treatment in evaluations. While indicators such as the number of women involved provide some sense of gender impacts, they do not reflect the medium- and long-term change in societies' perceptions and inclusivity towards women, nor enforce change. In the next section we outline some measures that can help realize and track gender-related impacts.

Future Opportunities for Realizing DIs through Renewables and Energy Efficiency

CTF's programmatic approach, as also described in a similar case study,[19] was deemed effective and provides a strong model for the continued effort to transform and decarbonize Türkiye's energy sector. Thus, Türkiye could benefit from continuing CTF's two-pronged strategy of increasing energy efficiency investments to reduce total energy consumption while further promoting the development of RES.

As pointed out by stakeholders, the participating development banks continued to finance energy efficiency and RES projects after the end of the project, and the government is looking to further develop opportunities with CTF and other MDBs that will support the deployment of these technologies.[20] Achieving further emission reductions and sustainability will require an enabling policy environment combined with sufficient loans to enable continued private sector action. Türkiye's road to a low-carbon economy requires continued cooperation among the government, the private sector, and international financial partners.

Community involvement in future projects

Increased local community involvement in future projects would be beneficial, as it results in local job creation and increases incomes for those involved. Local community involvement can be supported by engaging in multiple ways (e.g., via social gatherings, trainings, workshops) to familiarize communities with the projects in their vicinity. Later, local residents can sign up to contribute to these projects and benefit from these projects in a multitude of ways. Local involvement can result in newly developed supply chains and markets for certain services (e.g., capacity building around energy efficiency measures) as well as increased energy access. Local involvement is also key to earn community acceptance, which is generally only achieved if the developer can demonstrate that there will be no negative impacts, such a degradation of agricultural land, noise pollution, health impacts, etc.

More RES and energy efficiency projects to be realized in remote parts of Türkiye

Outside cities and urban areas, CTF funds could focus on specifically developing or scaling up RES and energy efficiency projects and services in rural and remote areas to reduce energy poverty in these locations. Decentralized energy generation is safe and reliable, and it improves the livelihoods and economic opportunities of many non-affluent rural people.

Decarbonizing SMES with RES

Decarbonizing SMEs with RES and energy efficiency investments would help boost Türkiye's progress on climate targets and make some products more affordable. Targeted investments in rooftop solar, small-scale PV farms, or more efficient machinery could improve the financial situation of many small businesses.

Enhancing gender-related benefits

Successful strategies to realize gender impacts in future projects are outlined below. These suggestions, based in part on CTF case studies from Haiti and the Maldives,[21] include:

- Involve local women and gender experts in the design stage of the program to identify barriers and solutions to women's participation.
- Promote and establish quotas for women's employment and training during project construction and ongoing operations, while enabling women to actively participate in decision-making roles.
- Enable a conducive environment for women's microenterprise development by reducing energy tariffs for female-led enterprises.
- Establish quotas ensuring that women occupy a minimum percent of the training spots provided to main energy suppliers and other project implementation partners.

- Campaign to raise awareness of RES/energy efficiency/household demand side management (based on what the project aims to achieve). Design these efforts to be gender inclusive and achieve 50 percent female participation, targeting female household consumers and women's groups in the target country.

Future Research and Future Opportunities

We recommend further work on the following topics:

Gender impacts of small-scale renewables: In May 2022, CIF published a guidance note on gender integration in project design based on good practices, which would be a good starting point for measuring the gender-related impacts of small-scale renewable energy projects.[22]

Coordination with local stakeholders and NGOs: Dialogue with local communities and NGOs to create buy-in for local RES projects to demonstrate the benefits and how potential local negative environmental and social impacts can be mitigated.

Community and regional economic benefits: Track indicators on community and regional economic benefits, in terms of local share of procurements, economic growth, employment, and gender equity in the renewable energy and energy efficiency field, relating to direct or indirect impacts.

Current hybrid RES policy: The current policy of hybrid RES is also interesting to pursue—any kind of existing power plant is currently allowed to double the installed capacity with solar PV under the condition that the supplied electricity does not exceed the amount agreed upon at the connection point. This is especially popular for wind parks, which makes their supply forecast to the connection point more predictable.

Table 3. Interviewee List

Name/Focal Point	Designation	Organization
Jari Vayrynen	Task Team Leader*	World Bank
Shinya Nishimura	Task Team Leader	World Bank
Sameer Shukla	Task Team Leader	World Bank
Yasemin Orocu	Project team member, Ankara office	World Bank

* Jari Vayrynen was the responsible concluding TTL, with Shinya Nishimura and Sameer Shukla being involved during the project design and implementation stage of the project.

Endnotes

1 See the International Energy Agency (IEA) country profile for Türkiye: https://www.iea.org/countries/turkiye. Note that hydropower remains the single largest renewable energy source, and in 2021, partly due to drought, output was lower than it had been in 2020. See also: IEA (2021). Turkey's success in renewables is helping diversify its energy mix and increase its energy security. https://www.iea.org/news/turkey-s-success-in-renewables-is-helping-diversify-its-energy-mix-and-increase-its-energy-security

2 IEA (2021). Turkey 2021: Energy Policy Review. Paris: International Energy Agency. https://www.iea.org/reports/turkey-2021.

3 See the IEA country profile for Türkiye: https://www.iea.org/countries/turkiye as well as: IEA (2021). Turkey 2021: Energy Policy Review.

4 Turkey Economic Monitor, World Bank: Turkey Economic Monitor: Sailing Against the Tide (worldbank.org)

[5] Turkey Economic Survey, Executive Summary, OECD (2021): TURKEY-2021-OECD-economic-survey-executive-summary.pdf

[6] This information was provided in interviews with IBRD/TTLs and was confirmed by a project staff member at the WB's Ankara office.

[7] World Bank (2016). Implementation Status Results Report. http://documents.worldbank.org/curated/en/800781482925198934/Turkey-Private-Sector-Renewable-Energy-and-Energy-Efficiency-Project-P112578-Implementation-Status-Results-Report-Sequence-11

[8] IEG (2017). Implementation Completion Report (ICR) Review. http://documents.worldbank.org/curated/en/670411510945091527/Turkey-PVT-SECTOR-RE-and-EE

[9] These departments mainly provide 'translation services' to translate the energy savings into cash flow gains for clients, similar to due diligence functions.

[10] IEG (2017). Implementation Completion Report (ICR) Review.

[11] Impact Assessment of the CTF in Renewable Energy and Energy Efficiency Market in Turkey, CTF (2013): https://www.climateinvestmentfunds.org/sites/default/files/knowledge-documents/ctf_impact_assessment_report_final_130528_0.pdf

[12] A more in-depth modeling of health impacts resulting from reduced air pollution via RES can be found in the case study "Scaling up solar power technologies in India," as part of the CIF DI MME.

[13] IEA (2021). Turkey 2021: Energy Policy Review.

[14] Regulation on air pollution caused by industry, ECOLEX (2009): https://www.ecolex.org/details/legislation/regulation-on-air-pollution-caused-by-industry-lex-faoc090590/

[15] Turkey's energy transition: milestones and challenges, World Bank (2015): https://documents1.worldbank.org/curated/en/249831468189270397/pdf/ACS14951-REVISED-Box393232B-PUBLIC-EnergyVeryFinalEN.pdf

[16] IEG (2017). Implementation Completion Report (ICR) Review.

[17] According to one of the team task leaders, Apex institutions similarly channel funding (grants, loans, guarantees) to multiple (micro-)FIs.

[18] IEG (2017). Implementation Completion Report (ICR) Review.

[19] CTF (2022). Transformational change in Turkey's energy efficiency: CTF's contribution.

[20] CTF (2022). Transformational change in Turkey's energy efficiency: CTF's contribution.

[21] Gender Action in Haiti and the Maldives – how the Climate Investment Funds aims to achieve gender balance in Renewable Energy, CIF (2022): Gender Action in Haiti and the Maldives – how the Climate Investment Funds aims to achieve gender balance in Renewable Energy | Climate Investment Funds

[22] Gender integration guidance note for Climate Investment Fund projects, CIF (2022): https://www.climateinvestmentfunds.org/sites/cif_enc/files/knowledge-documents/cif_gender_integration_guidance_note.pdf