Energy Storage Solutions:
A preliminary financial analysis has been carried out by running simulations in System Advisor Model (SAM) for a candidate storage solutions project. As the site is still in process of being identified, the model is based on number of assumptions as listed below. Model has been run for Rewa Solar Park site in the state of Madhya Pradesh and an inbuilt typical meteorological year (TMY) file for the same site is used. Modelling has been carried out for 50 mega-watt hour (MWh) storage for Lithium Manganese Oxide (LMO) with US$380 per unit (kilo-watt hour, kWh) direct current (DC) and 50 mega-watt (MW) solar block.

Assumptions:
In addition to above, following technical assumptions are used in the model:
1. Yearly production: Considered a DC:AC overloading of 30% which increases the expected yearly generation. Resultant capacity utilization factor (CUF) could reach 23.74% in ideal scenario.
3. Panel degradation factor: The factor must also include degradation of other components apart from modules. A system degradation factor of 0.8% per annum has been assumed.
4. Inflation: An inflation at 5.5% per annum has been assumed.
5. Operations and Maintenance (O&M) cost: An O&M cost of INR 350,000 per MW (US$5/kW/year) for a solar block is considered. For storage block, US$10/kW/year is considered. It takes into account the discount offered by Indian companies.
6. Interest rate: at 10% has been considered.
7. Battery replacement cost: battery replacement threshold of 80% has been used as a benchmark. It means, if the battery performance falls below 80% of its capacity, there will be adequate replacement in battery to bring performance back to 80%. This is a continuous process over the useful life of the plant. Other option of bulk battery replacement after a fixed number of years has not been considered in the model.

Financial Model - Results:
Following are the result of simulations in SAM. Two scenarios are modelled in SAM - one without storage (base case) and second with storage. Both the scenarios doesn’t factor in CTF funds. Table 1 shows the results for these two scenarios.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Base Case: 50 MW solar bloc + no storage (no CTF grant)</td>
</tr>
<tr>
<td>Annual energy (year 1)</td>
<td>100,626,952 kWh</td>
</tr>
<tr>
<td>Capacity factor (year 1)</td>
<td>17.70%</td>
</tr>
<tr>
<td>Energy yield (year 1)</td>
<td>1,548 kWh/kW</td>
</tr>
<tr>
<td>Battery efficiency</td>
<td>0.00%</td>
</tr>
<tr>
<td>PPA price (year 1)</td>
<td>4.09 ¢/kWh</td>
</tr>
<tr>
<td>Net present value</td>
<td>$1,229,597</td>
</tr>
<tr>
<td>Internal rate of return (IRR)</td>
<td>11.00%</td>
</tr>
<tr>
<td>IRR at end of project</td>
<td>19.16%</td>
</tr>
</tbody>
</table>
Financial Model - Interpretation of Results:

There is a clear increase in power purchase agreement (PPA) prices from US 4 to 7 cents for addition of 50 MWh storage, that is, a difference of 3 cents per unit due to addition of storage. Standalone solar tariffs are falling rapidly in India (currently at US 4 cents/unit) on account of sharp decline in solar module prices, achieving of economies of scale and clear national policies on solar. Amongst other consumers, distribution companies (discom) stand out as the main off-takers of solar power. Discoms are obligated to buy a certain percentage of solar power under Renewable Power Obligations (RPO), however RPOs are yet not enforced strictly in India. Further, even though solar power has reached grid parity, power is available at less than 4 cents per unit on the power exchange. Due to financial distress, these discoms are commercially very sensitive and hence creating a tremendous pressure to further reduce solar tariffs. Despite the impending need to ensure stable grid operations, ensuring consistent availability of power through renewable sources and other advantages that battery storage technologies bring, the financial health of discoms doesn’t justify the higher tariff of 7 cents for a solar storage system. With a battery bank of 50 MWh at US$380/kWh DC, a viability gap funding of around US$20 million is required to make such projects commercially viable by bringing such PPAs equivalent to US 4 cents/unit.

Hence, it is important to have CTF grant as viability gap funding for storage component to demonstrate the financial and technical benefit of storage to a renewable energy project.

Ideally, the system to which the plant connects would have a quantified view of the value of storage. For example, by calculating the expected solar photovoltaic (PV) curtailment and offsetting it against the price of storage to reduce curtailment, by being aware of the value of incremental peak capacity etc. With that, the offtaker can establish a threshold value for a sustainable cost of storage. One example is the state of Hawaii, where utilities require specific storage capacity to be coupled with additional solar PV capacity based on their estimate of the cost and benefit. However, most systems do not have that visibility today, and lack of data from storage operations on their grid is one reason. The project will help deploy storage without a fully formed business case, and then to generate operational data that will help build the business case for subsequent, fully commercial projects in India.

Economic Model – Results and Analysis:

The economic model is based on the same assumptions as for the financial model section. The economic analysis is based on simplistic scenario looking at following factors:

a. **Avoided Greenhouse Gas emissions:** The proxy for the same has been assumed as avoided generation from the fossil fuel (coal) based thermal generating plants. Given the plant size (solar with storage) as mentioned above, about 100 GWh will be generated through the project in year 1, which results in avoided GHG emissions of 82.4 thousand tons and economic value of almost about US$2.7 million to the economy.

b. **Avoided variable cost:** In addition to the avoided GHG emissions, another economic benefit of the project is the total amount of coal fired power generation that has been

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1 As per recent estimates, total accrued losses by discoms stand at around US$36 billion, as a result of weak governance, low regulatory support (often resulting in below-cost-recovery tariffs), high aggregate technical and commercial losses, and poor commercial performance.
avoided due to the presence of a 50 MWh of storage project. The proxy for the same is the avoided variable (fuel) cost for such power generating stations, which will not need to be kick-started due to faster response time of the battery. In the year 1 of operations, the project will save about US$4.7 million towards fuel.

c. **Benefits to local population:** It is assumed that about 2 million (these are rough estimates) people are expected to benefit out of such a project. Health cost (or damage cost) associated with the affected population being exposed to high levels of NOX, PM-10 and SOx is taken as a proxy for such benefits to the local population. Such ‘damage cost’ is escalating at a marginal rate to reflect increased expenses towards decrease in the level of productivity of project affected people, increase the tax dollars spent on treating project affected people through public health institutions and spending tax dollars on reversing environmental impacts of the society/community. Avoided Coal (which is represented in a dollar amount) stands as a proxy for the per capita GDP of such project affected people. With battery substituting coal fired generation plants, such costs are avoided.

Based on the above, the economic rate of return of the project is 10.8%, which is above the benchmark rate of 10%. Further, the above analysis doesn’t factor in the avoided/deferred investments in augmenting or strengthening transmission system. It also doesn’t factor in economic value that storage brings in through bringing grid stability, peak shaving, reducing variability of renewable energy and other positive impacts, all of which may not be quantified.

**Floating Solar PV System:**
The financial and economic analysis has been conducted for the floating solar investment. A 10 MW site in Ramgiri in Anathapur district in Andhra Pradesh has been considered for installation of the floating solar plant.

**Assumptions:**
Following assumptions are used in the model:
1. Total installed capacity - 10 MW
2. Project cost – US$11.4 million
3. Debt:Equity ratio - 70:30 (as per Central Electricity Regulatory Commission’s norms)
4. Return on Equity - @ 20% for the first 10 years & 24% from the 11th year (according to CERC norms)
5. Interest rate - @ 9% per annum
6. Operation & Maintenance (O&M) cost - @ Rs 7 Lakhs/MW (or US$10.7/kW/year) (escalated @ 5.72% per annum as per Central Electricity Regulatory Commission’s norms)
7. Capacity Utilization Factor - @ 19.74%
8. Loan repayment period - 12 years
9. Project life - 25 years (as per Central Electricity Regulatory Commission’s norms)

**Financial Model – Results:**
Following are the results of the financial model. Compared to ground mounted, floating solar plants are expensive to set up as the cost of floaters constitute almost 50% of the project cost. As compared to existing benchmark project cost of US$0.6-0.8 million/MW, floating solar almost costs US$1-1.2 million/MW. However, costs are declining due to countries like China aggressively looking at large installations of such plants, while other countries like Singapore, England, etc. are following it closely. The benefits however are observed in terms of higher CUF of solar panels as well as avoidance of scarce land.

As per regulatory norms, debt-equity ratio of 70:30 has been assumed for running the analysis. Further, given that the World-Bank-CTF project will finance 50% of the estimated project cost (US$11.4 million),
it constitutes little more than 70% of the debt component. The balance debt is to be raised by the borrower (SECI) on commercial rates. Given that the project size is small (10 MW), the contribution of CTF loan has been sized proportionately. IBRD loan expected to be about US$4.2 million while CTF loan of US$1.4 million. Two scenarios were run with the commercial rates at 9% and at 12%.²

Scenario 1 – commercial rate of interest at 9%:
Below table reflects the levelised tariff against the various scenarios of viability gap funding, with an extreme case where the VGF funding is estimated to bring floating solar tariff at parity with the current solar tariffs discovered in the country. Its observed that with both IBRD and CTF loans available, the resultant decrease in tariff is between 2.0%-2.5% depending on the VGF support envisaged, with the highest reduction corresponding to no VGF case. CTF has an impact of about 0.6%-0.8% in this fall in tariff.

<table>
<thead>
<tr>
<th>Head</th>
<th>Only Commercial Loan at 9%</th>
<th>Commercial Loan with IBRD and CTF</th>
<th>Commercial Loan with IBRD, without CTF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tariff (per unit)</td>
<td>Tariff (per unit)</td>
<td>Tariff (per unit)</td>
<td></td>
</tr>
<tr>
<td>INR</td>
<td>US Cents</td>
<td>INR</td>
<td>US Cents</td>
</tr>
<tr>
<td>no VGF</td>
<td>7.18</td>
<td>0.11</td>
<td>6.99</td>
</tr>
<tr>
<td>VGF of INR 1 cr (US$0.15 m) per MW</td>
<td>6.31</td>
<td>0.10</td>
<td>6.15</td>
</tr>
<tr>
<td>VGF of INR 5 cr (US$0.75 m) per MW</td>
<td>2.83</td>
<td>0.04</td>
<td>2.77</td>
</tr>
</tbody>
</table>

Scenario 2 – commercial rate of interest at 12%:
As per this scenario, if the commercial rate of interest increases, the resultant decrease in tariff with both IBRD and CTF is between 6.5%-8% depending on VGF support envisaged. In this scenario also, CTF has almost same impact as the above one in terms of basis points.

<table>
<thead>
<tr>
<th>Head</th>
<th>Only Commercial Loan at 12%</th>
<th>Commercial Loan with IBRD and CTF</th>
<th>Commercial Loan with IBRD, without CTF</th>
</tr>
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<td>Tariff (per unit)</td>
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<td></td>
</tr>
<tr>
<td>INR</td>
<td>US Cents</td>
<td>INR</td>
<td>US Cents</td>
</tr>
<tr>
<td>no VGF</td>
<td>7.78</td>
<td>0.12</td>
<td>7.15</td>
</tr>
<tr>
<td>VGF of INR 1 cr (US$0.15 m) per MW</td>
<td>6.83</td>
<td>0.11</td>
<td>6.28</td>
</tr>
<tr>
<td>VGF of INR 5 cr (US$0.75 m) per MW</td>
<td>3.02</td>
<td>0.05</td>
<td>2.82</td>
</tr>
</tbody>
</table>

The arguments as explained regarding off-taker/distribution company hold valid for this technology as well.

Financial Model – Interpretation of Results:
It is evident from the above matrix that without any viability gap funding, floating solar is much expensive than the ground-mounted solar PV system. Even at the high cost, project IRR stands at 11%.

Assuming that entire debt is raised from commercial sources, the preliminary financial analysis results in saving of about INR 2 million/MW of VGF if both IBRD and CTF funds are available (in proportions as

² As per recent Rural Electrification Corporation’s lending rates for the power sector, the interest rate for renewable energy sector for a central public sector undertaking (like SECI) is at 9.75%. Refer link for more details: http://www.recindia.nic.in/download/Interloan.pdf
mentioned above) while it results in savings of about INR 1.3 million/MW of VGF if only IBRD is available to this project (in scenario 1 with commercial interest rate at 9%). In scenario 2 with commercial interest rate at 12%, the savings turn out to be INR 5.74 million/MW when both IBRD and CTF is deployed while in INR 5.2 million/MW if only IBRD is made available to the project, with a base case being 100% commercial debt financing for the project.

The levelised tariff without VGF is upwards of US 11 cents and hence for its uptake as well as for opening up the market, it is important to boost this technology through concessional support as proposed to come from CTF. Further, given that the technology is being scaled up across the globe, the costs especially of floaters will come down and hence giving another push to adoption of this technology. Indigenization of floaters will also play an important role in bringing the costs of floating solar projects.

**Economic Model – Results and Analysis:**
The methodology for economic model remains the same as for storage technology. The economic analysis is based on the same assumptions as for the financial model section. The economic analysis is based on simplistic scenario looking at following factors:

a. **Avoided Greenhouse Gas emissions:** The proxy for the same has been assumed as avoided generation from the fossil fuel (coal) based thermal generating plants. Given the plant size of 10 MW, about 17.3 GWh will be generated through the project in year 1, which results in avoided GHG emissions of 14.3 thousand tons and economic value of almost about US$0.5 million to the economy.

b. **Avoided variable cost:** In addition to the avoided GHG emissions, another economic benefit of the project is the total amount of coal fired power generation that has been avoided due to the presence of a 10 MW of storage project. The proxy for the same is the avoided variable (fuel) cost for such power generating stations, which will not need to be kick-started during time of generation of solar power. In the year 1 of operations, the project will save about US$0.8 million towards fuel.

c. **Benefits to local population:** The benefits from a 10 MW plant are marginal and not giving substantive values to be factored in for the analysis. Nonetheless, benefits accruing to local population cannot be discounted and holds a positive correlation with the economic rate of return.

Based on the above, the economic rate of return of the project is 11.6%, which is above the benchmark rate of 10%. Further, the above analysis doesn’t factor in the avoided land cost, alternative uses of the scarce land, saving on evaporation loss from the water body, which will have positive impact on economic rate of return.