CIF CLIMATE INVESTMENT FUNDS

# Breakout Sessions: Customizing Business Cases to Country Context and Needs

# Breakout Session 1: Battery Storage

**Moderator:**

Tom Beierle,
*Ross Strategic*

**Amit Jain,** Senior Energy Specialist, World Bank: *Focus on Maldives battery energy storage project*

**Dr. Pimpa Limthongkul**, Energy Storage Research Team Leader, and **Dr. Jiravan Mongkolthanatas**, Energy Storage Research Team Researcher, National Energy Technology Center (ENTEC) *Focus on battery storage technology projects in Thailand*

**Peter Langley**, Project Manager, RT&D Large Scale Energy Storage Test & Demonstration Facility, ESKOM: *Focus on battery storage technology research in South Africa.*

#KeepingthePowerOn

# Breakout Session 2: Long Duration and Utility-Scale Storage

**Moderator:**

Tim Larson,
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**Abderrahim Jamrani**, Engineering Director, Masen (Moroccan Agency for Solar Energy): *Focus on Morocco project combining concentrated solar power (CSP) and thermal energy storage*

**Felipe Verástegui Grünewald**, Green Hydrogen Specialist, New Energy Carriers Unit, Chilean Ministry of Energy: *Focus on Chile's National Green Hydrogen Strategy*

**Brennan T. Smith**, Water Power Program Manager, Oak Ridge National Laboratory. *Focus on pumped hydropower storage*

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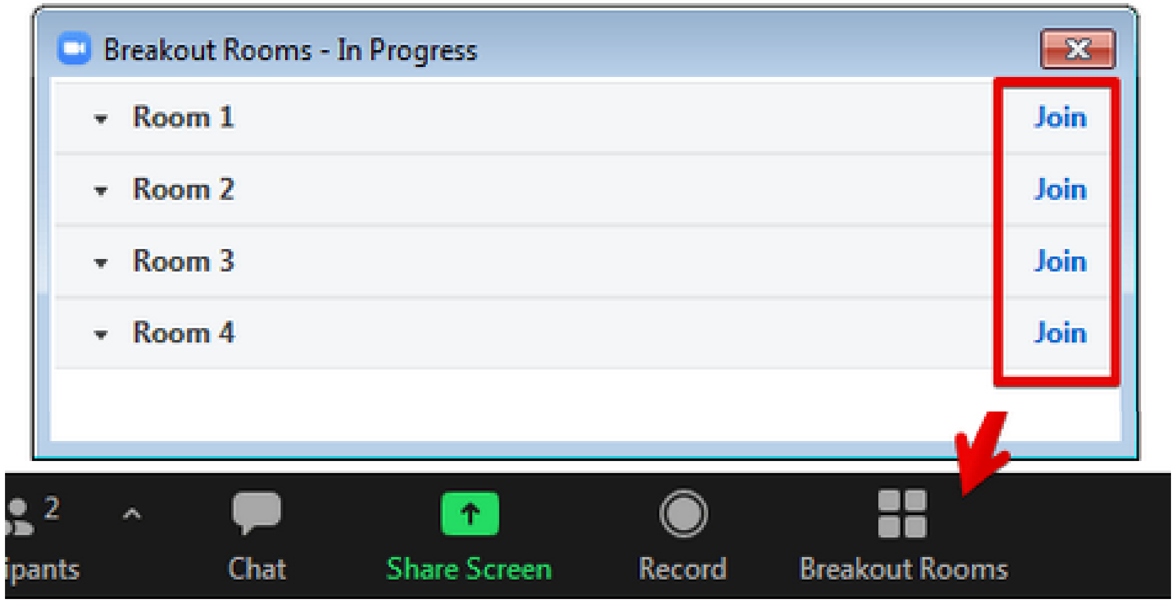
# Please Join One of the Following Breakout Rooms

**Room 1: Battery Storage**

**Room 2: Long Duration and Utility-Scale Storage**

- To select a room:
  - Click **Breakout Rooms**
  - Hover over the room of your choice and click **Join**
  - You can also navigate between rooms using the same controls



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# MALDIVES: THE LAND OF SUN, SEA, SAND AND SUSTAINABILITY

**GESP- KEEPING THE POWER ON**

**(July 14, 2021)**

**Amit Jain**

**@AJ_WorldBank**

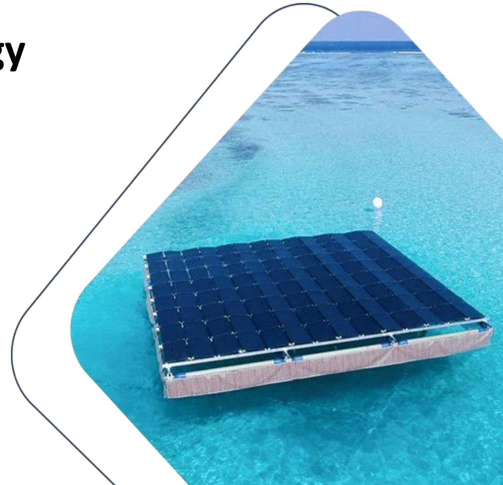
# MALDIVES: CLIMATE CHANGE IMPACT and RISING VULNERABILITIES

## Climate Impact

- **Lowest lying country:** Average natural ground levels of only 2.4 meters and 1.5 meters above sea level
- **Sea level rise:** Around 200 natural inhabited islands could be submerged by 2100 with some of the low-lying islands disappearing as early as 2050.

## Maldives Government RE Targets and World Bank Support

- **Net Zero Target:** By 2030 announced by President Solih at the UN Climate Ambition Summit 2020.
- Achieved **USD 10.9 cents** in SPV bid. Lowest for island nation at time of bid opening.
- USD 107 million plus **ARISE (2020)** project: Focused on **Solar PV, Battery Storage and Grid Upgrades.**
- Project co-funded by **Asian Infrastructure Investment Bank (AIIB)- USD 20 million** and **Clean Technology Fund (CTF) USD 30 million**
- **Energy Storage Roadmap Study (2019)**
  - 5 islands: carbon dioxide ($CO_2$) emissions of the Maldives by ***445,000 tonnes*** over the period 2020 to 2040.
  - saving of ***US$14.7 million***



# STORAGE ROADMAP: SUMMARY

## BESS is critical for the Maldives

- Mitigating outages, providing spinning reserve, and facilitating the integration of Electric Vehicle (EV) charging

Summary of Study Results for Each Island

| | Greater Male | Addu | Fuvahmulah | Hulhumeedhoo | Thimarafushi |
|---|---|---|---|---|---|
| PV Capacity* (MW) | 10.0 | 11.6 | 5.0 | 2.0 | 1.0 |
| BESS Capacity* (MW) | 10.0 | 8.4 | 5.0 | 2.0 | 1.0 |
| BESS Energy Capacity* (MWh) | 40.0 | 33.6 | 20.0 | 8.0 | 4.0 |
| Diesel Capacity* (MW) | 191.3 | 24.0 | 7.6 | 1.6 | 1.2 |
| Total Capacity* (MW) | 211.3 | 44.0 | 17.8 | 5.6 | 3.2 |
| PV Investment** (US$ million) | 14.3 | 16.8 | 8.4 | 3.4 | 1.7 |
| Battery Investment** (US$ million) | 12.8 | 12.8 | 6.4 | 2.6 | 1.3 |
| Total Diesel and Lube Oil Savings** (US$ million) | 32.2 | 34.0 | 18.8 | 8.0 | 3.4 |
| $CO_2$ Reduction** (kilotonnes) | 140.2 | 163.5 | 89.5 | 37.3 | 14.8 |
| PV+BESS LCOE (US$/kWh) | 0.140 | 0.097 | 0.111 | 0.111 | 0.111 |

# ARISE STATUS: BATTERY STORAGE PQ RELEASED

## ARISE Component 2: 40 MW/ 40 MWh Battery Energy Storage System PQ

- *Capacity is divided in two lots:*
  - *24 MW/24 MWh*
  - *16 MW/16 MWh*
- *USD-23-million concessional loan from the Clean Technology Fund to cover for the installations under the BESS tender.*
- *RFP can be accessed on: https://finance.gov.mv/tenders*

- An initial capital investment of US$ 80.4 million in solar PV and BESS, the Maldives would save US$ 96.4 million on diesel and lube oil expenses over 20 years, would defer US$ 17.5 million in capital expenses of diesel generator purchases, and reduce carbon externalities by US$ 13 million.

# BESS Case Study in Thailand

CIF – GEP EVENT: KEEPING THE POWER ON

THE BUSINESS CASE FOR EMERGING ENERGY STORAGE TECHNOLOGIES

ENTEC

a member of NSTDA

14 July 2021

Pimpa Limthongkul

Jiravan Mongkoltanatas

National Energy Technology Center (ENTEC)

National Science and Technology Development Agency

Pathumthani, Thailand

# BESS with Solar/Wind Farm (On-Grid App.)

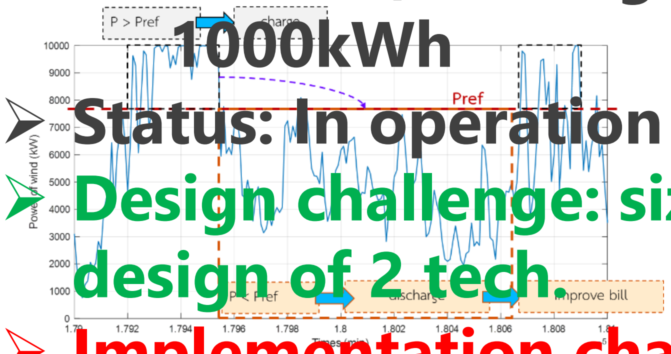
ENTEC a member of NSTDA

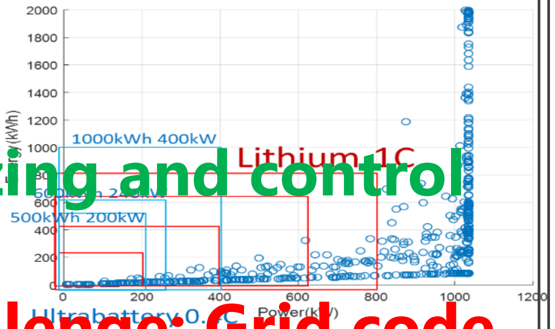
OD in 2019

## Battery System coupled w/ Wind (10MW)

Lom Ligor: 1st BESS with wind in MW scale in Thailand

- **Energy Source: Wind 10 MW with PPA 8.965 MW**
- **Application: Electric Bill Management with Renewables**
- **2 different technologies**
  - **Li-ion 600kW 600kWh**
  - **Ultrabattery 600kW(discharge)/400kW(charge) 1000kWh**
- **Status: In operation**
- **Design challenge: sizing and control design of 2 tech.**
- **Implementation challenge: Grid code**



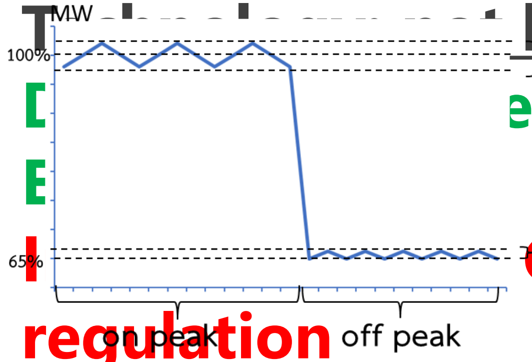



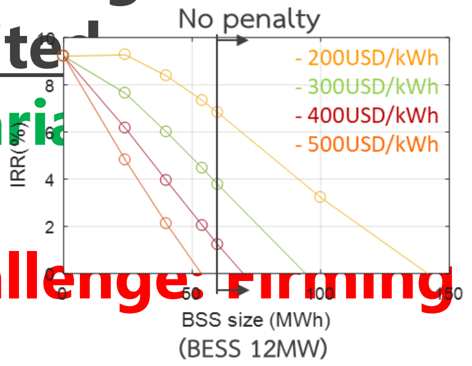

COD in 2022

## Battery System coupled w/ PV

SPP Hybrid Firm

- **Energy Source: PV**
- **Application: Renewable capacity firming**
  - **Guaranteed constant profile @ peak hr (w/ penalty)**
  - **Limited payment during off-peak**
- **ESS not stated as requirement but proposed during bidding**
- **T… limite**
- **D… e: varia**
  **E**
- **I… Challenge: Firming regulation**



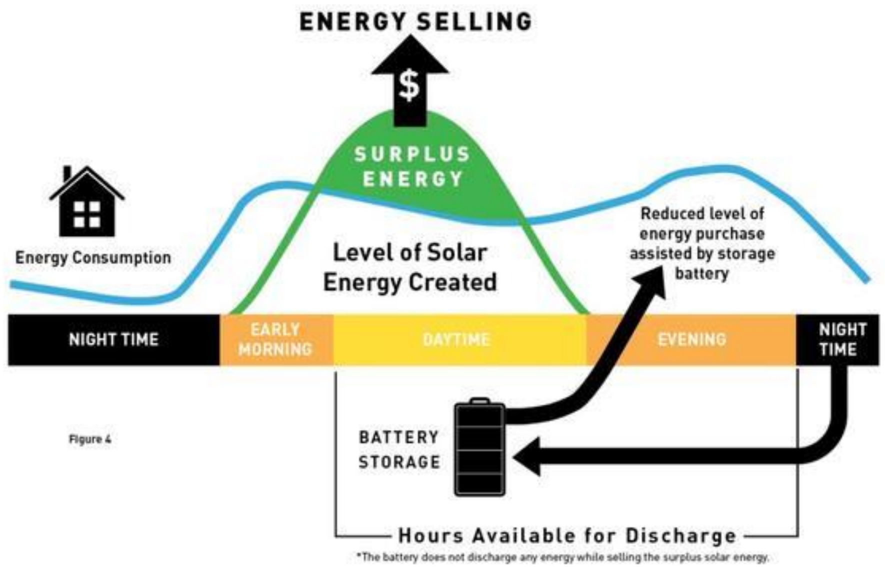



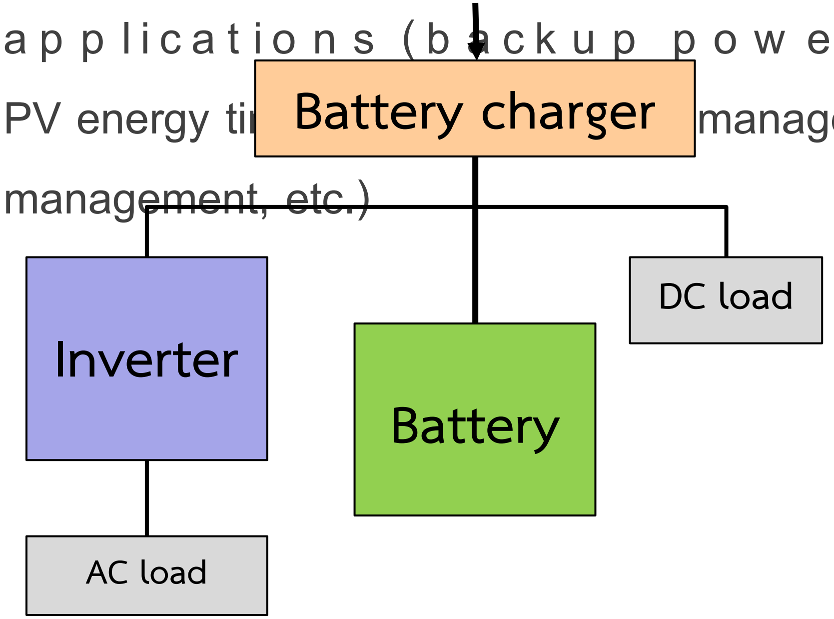
# BESS for Stacked App in Power Plant

ENTEC
a member of NSTDA

## Implementation of PV for power saving + ESS (stacked app)

- Critical load => require high reliability
- Current UPS system : Lead acid battery
- Interested in
  - Change technology (Lead acid battery -> Lithium ion battery)
  - ESS coupling with PV for stack applications (backup power (as UPS), PV energy ti management, etc.) management, etc.)




**Challenges:**

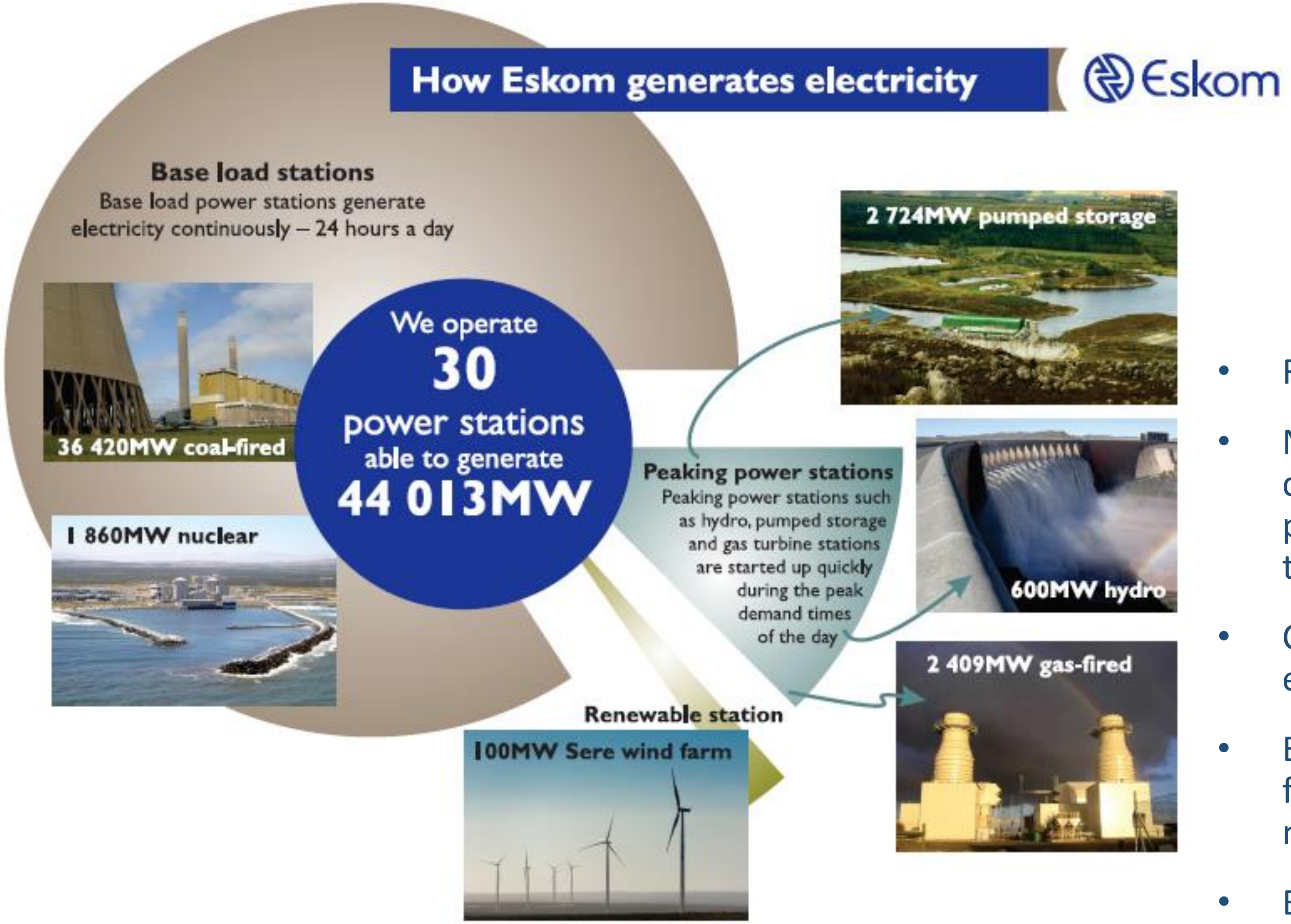
- Operating DC voltage of load <-> Lithium ion battery
- For stacked application
  - Challenging in Reconfigure system diagram
  - Challenging to find PCS that can transfer from normal operation (on grid) to emergency operation (islanding) within < ms

# Climate Investment Funds Energy Storage Technology Event

July 14th 2021

Peter Langley

# Our Current Generation Profile & IRP2019




- Requirement for Eskom to become more flexible.
- Neither solar PV, nor wind can be regarded as despatchable resources however wind+PV is looking promising in South Africa and need to be integrated into the existing and future power system.
- Cannot be relied upon to supply a constant source of energy.
- By 2030 Eskom will need to able to accommodate fluctuations of as much as 16.8GW during the day and also meet a peak demand of up to 12GW (July).
- Base load stations, nuclear and coal fired can accommodate some fluctuation in load but at a high cost.

Eskom

# Energy Storage in Eskom

**Drakensberg Pumped Storage**

Installed capacity: 1000MW

(for 28 hrs)

*1981*

**Palmiet Pumped Storage**

Installed capacity: 400MW

(for 28 hrs)

*1988*

**Ingula Pumped Storage**

Installed capacity: 1332MW

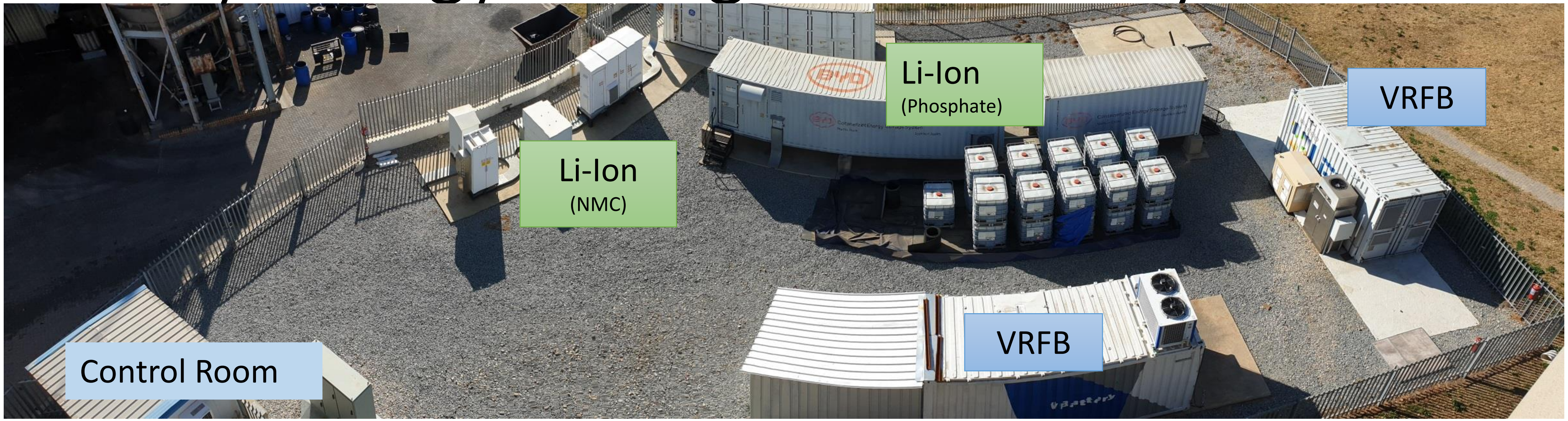
(for 14 hrs)

*2017*

**Battery Test Facility**

*2015*

# Battery Energy Storage Test Facility



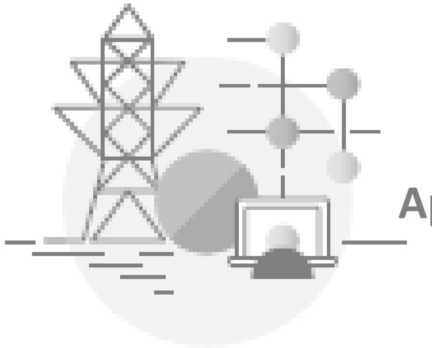

Objectives:

1. Demonstrate the effectiveness of battery energy storage at a grid scale.
2. Test individual battery technologies under real operating test regimes
3. Identify the best technology for various applications
4. Establish the probable life cycle of each of the various technologies under real working conditions
5. Establish the round trip efficiencies of the various units
6. Give Eskom insight into the future installation of commercial battery storage units of the Megawatt scale.

Eskom

# Energy Storage Research Activities

**Technology**



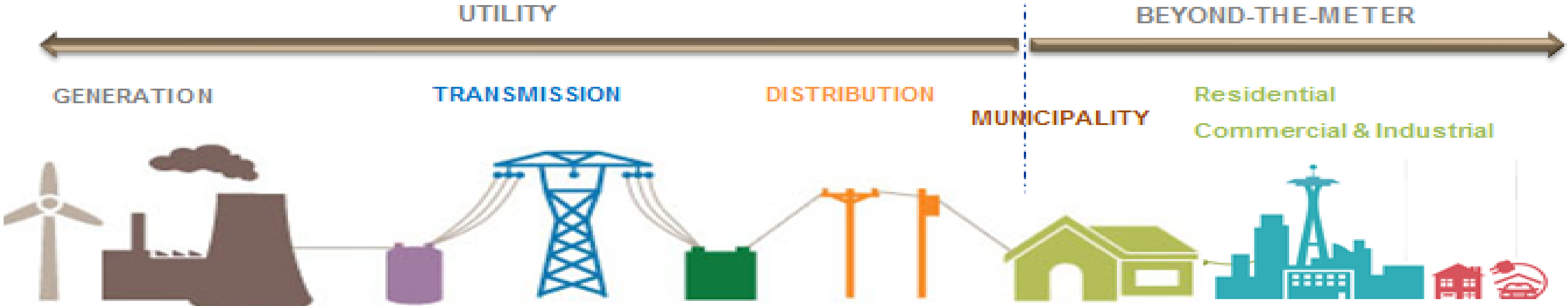
**Application**

- Tracking and trending of energy storage technologies and developments
- Performance testing of battery energy storage
- Energy storage technology development

- Identifying opportunities for energy storage application across the energy value chain
- Operational implementation requirements

Eskom

# Energy Storage in Eskom




**Generation**
- Impact of Min-Gen and flexible operation on plant performance, environmental compliance and operational variable costs
- Use of more expensive generation during valleys and peaks
- Cost of Curtailment of IPPs
- Black Start

**Transmission**
- Power Quality issues
- IPP integration
- Network stability and substation loading
- Constrained networks
- Network (wires) overloading (Capacity & Thermal)
- Load Balancing issues

**Distribution**
- Constrained networks
- Customers RTPV
- Poor & aged infrastructure
- Substation lack of capacity & transfer capability
- RE integration – no protection & stds and FIT promulgation

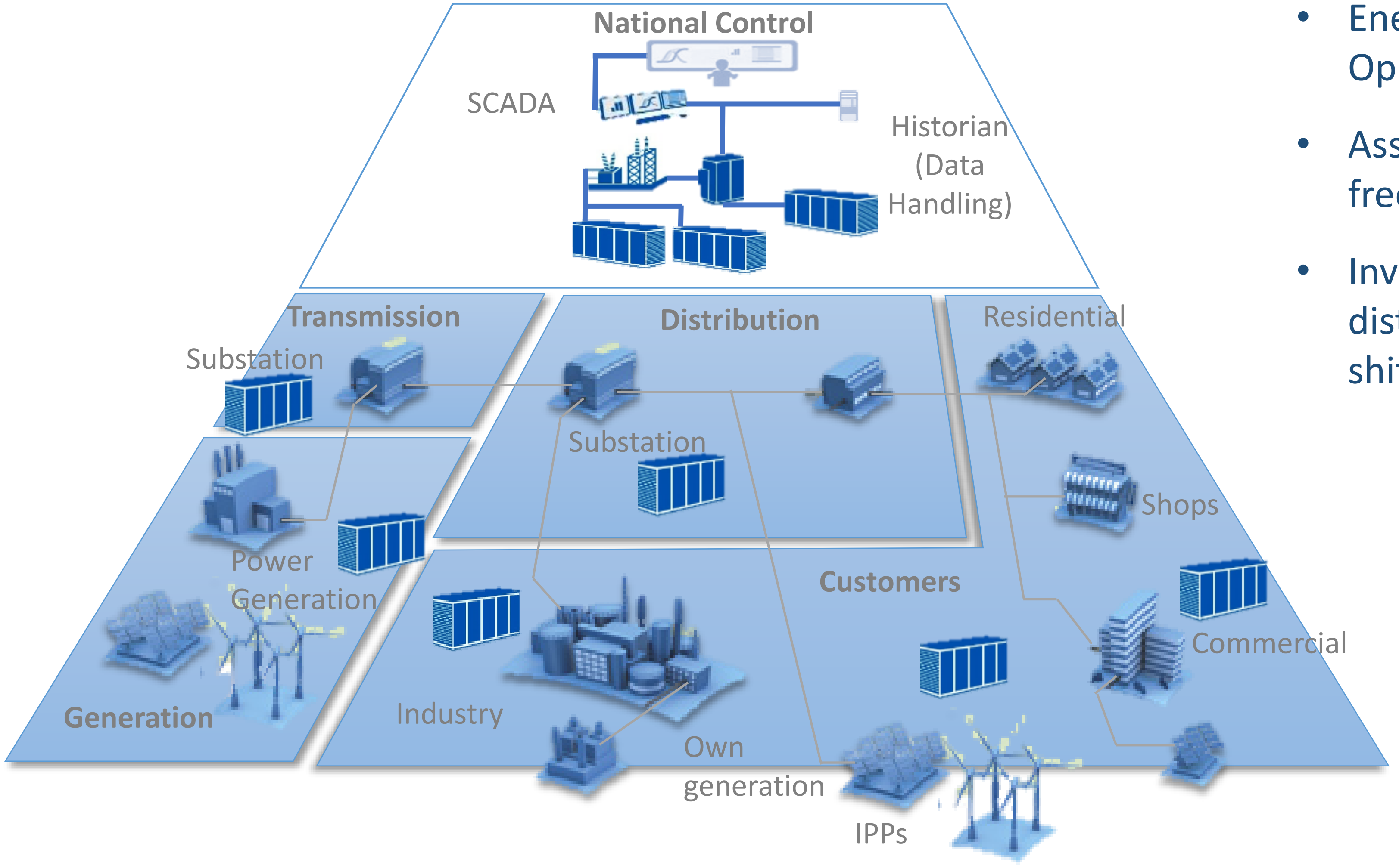
**Beyond-the-meter**
- Limited in terms of new or upgrade of supply connection
- Reliability of supply challenges
- Impact of un-regulated DG on grid – no control
- Risk of tariff increases
- Competitors providing alternatives – loss of customers and revenue

**Challenges in Energy System**

**Opportunities Identified**

- Improve the performance of the organisation
- Retain existing, attract new and re-acquire former customers to the organisation
- Create new business opportunities
- Create new revenue streams

# Energy Storage – Flexible and Agile Solution




- Energy storage can assist the System Operator in balancing Supply and Demand
- Assist with system operation (i.e. frequency control, flexible ramping, etc.)
- Investment deferral – transmission and distribution congestion relief, and energy shifting and capacity investment deferral

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# Abderrahim Jamrani, Engineering Director, Masen (Moroccan Agency for Solar Energy)

*Focus on energy storage in Morocco*

# STORAGE TO ENHANCE RENEWABLES PENETRATION INTO GRID

masen

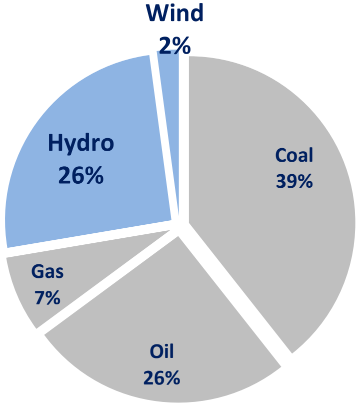
endless power for progress

July 2021

# RENEWABLE ENERGIES, AT THE HEART OF MOROCCO'S ENERGY STRATEGY

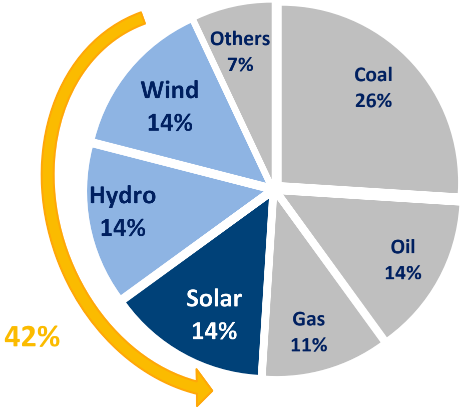
**Strong will of increasing renewable energy share within the national mix by 2020 and 2030, through a roadmap of deployment based on an optimal technological mix**

## 2009



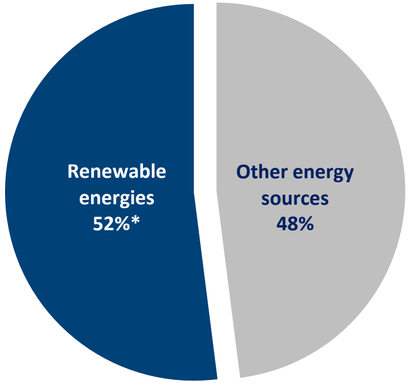

**Renewable energy represented 28% of installed capacity**

## 2020




**Renewable energy will represent 42% of installed capacity**

## 2030




**Renewable energy will represent 52% of installed capacity**

Conventional energy

Renewable energy

Projects developed/to be developed by masen

# MASEN : A DEDICATED ACTOR RELYING ON A STRONG LEGAL AND INSTITUTIONAL FRAMEWORK…

## *Legal framework*

**2009** — Law 57-09 initially establishing Masen

**Object**

Development of solar integrated projects with a target of at least 2000 MW by 2020

**Legal Form**

Limited liability company, created in March 2010

**Shareholding**

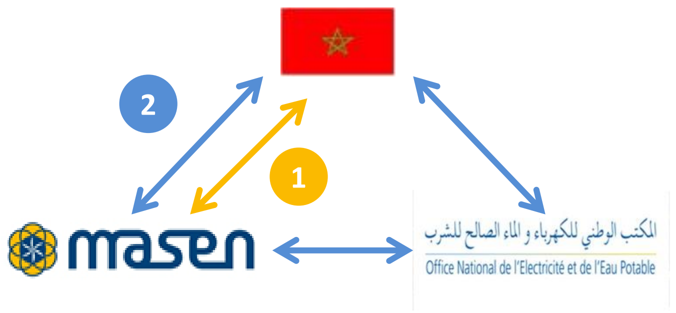
State, ONEE(1), Hassan II Fund(2) and SIE(3) - equal shares

**2016** — Law 38-16 amending and completing the Law 57-09

**Object**

- Change of Masen's name from "*Moroccan Agency for Solar Energy*" to "*Moroccan Agency for Sustainable Energy*"
- Enlargement of Masen's scope from developing only solar energy plants to all types of renewable energy(4) in morocco and abroad

## *Institutional framework*




1. **State-Masen Agreement (decree):** Conditions, technical requirements and guarantee of the financial equilibrium of Masen's projects o
2. **State-ONEE-Masen Agreement:** Take or pay including terms and conditions for the purchase, supply, transport and commercialization of electricity produced

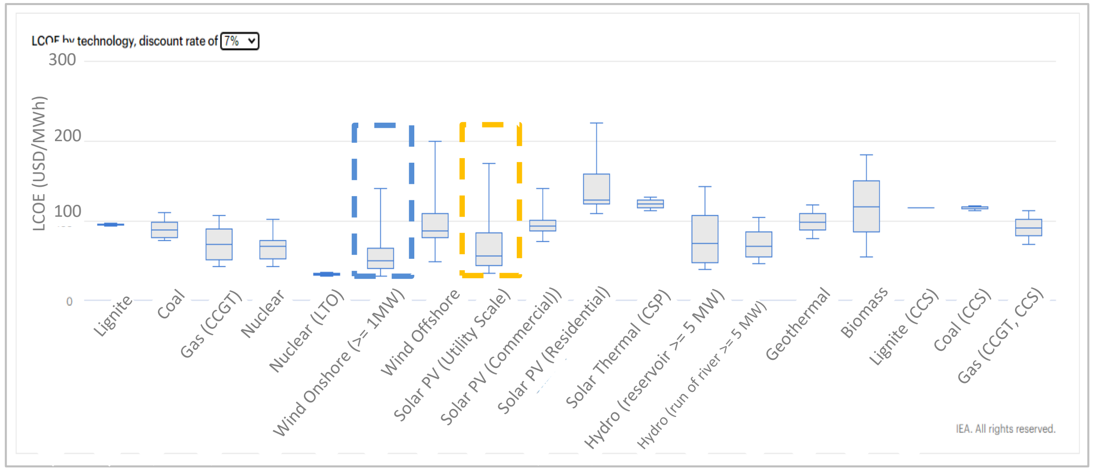
*(1) ONEE: Office National de l'Eléctricité et de l'Eau, the national utility*
*(2) Hassan II Fund for Economic and Social Development*
*(3) Société d'Investissements Energétiques*
*(4) Except the assets dedicated to the stabilization of the grid*

# PV & Wind : electrical production basis of the futur

**Wind and PV are the cheapest energies in Morocco : Energy less than 35 cMAD/kWh**

2 use cases

**Cheapest energy but depends on the availability of Wind and Sun**

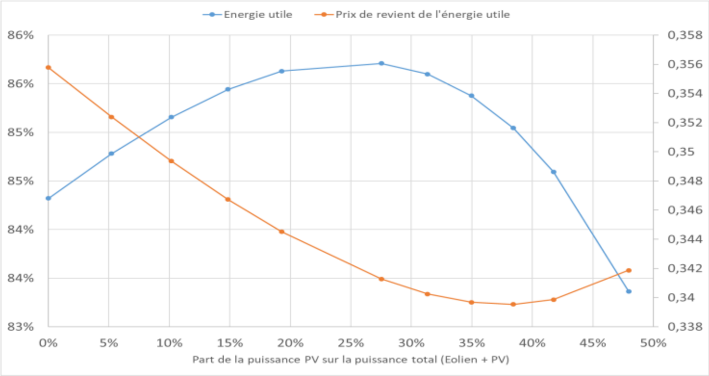



1 **Flexible Demand**
*Ex : Green H2 with salt cavern*

**Direct use of PV and Wind energy**

2 **Non-Flexible Demand**
*Ex : National consumption profile*

**Maximize Wind and Solar in the useful energy and satisfy the remaining need by <u>other technologies</u>**




**Sites Synergy**

**PV-Wind Synergy**

**Useful PV-Wind energy :**

**>= 80%**

masen

# Which approach for the Grid : Fossil energies (1/2)

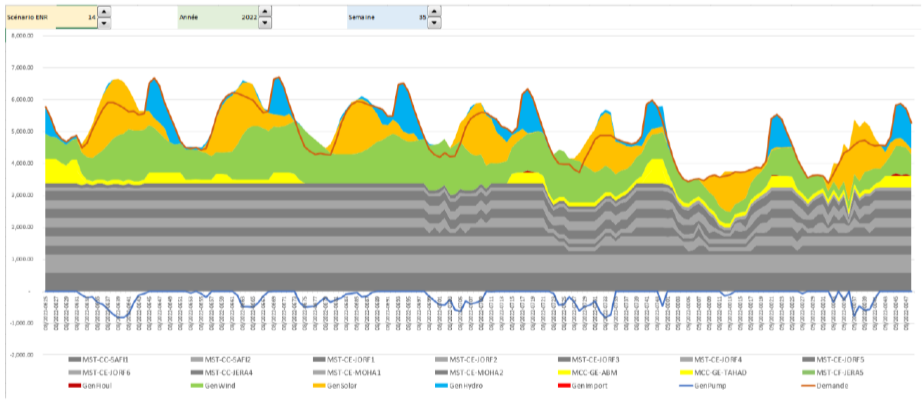
**As long as the renewable kWh is cheaper than the cost of the replaced fossil fuel, it would be more judicious for the electricity system to prioritize the renewable kWh and to reduce and/or stop thermal production within the technical limits required by the power plants.**

## Coal plants

- Low flexibility
- High fixed cost

→ **Negative impact on the kWh cost in case of shutdown or power reduction**

**Each new coal plant reduces the eventual capacity of the PV and Wind that can be integrated into the grid**




## Gaz to power

**Gas Pipeline**

Constant flow use → Same case as coal in base load

**LNG**

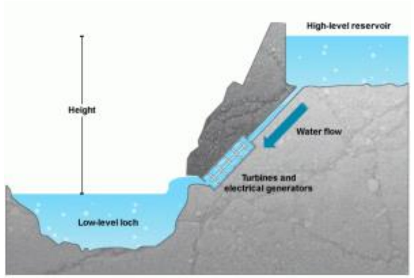
The use of LNG power plants dedicated to manage the RE intermittence can lead to **higher cost of the kWh** given :

- The use of LNG involves high import volumes ;
- High investment costs for the infrastructure with a low utilization factor ;
- Need for significant storage capacities to manage intermittence ;
- Low capacity factor of the power plant :

➔ **very high fixed cost per kWh produced**

# Which approach for the Grid : REN Storage (2/2)

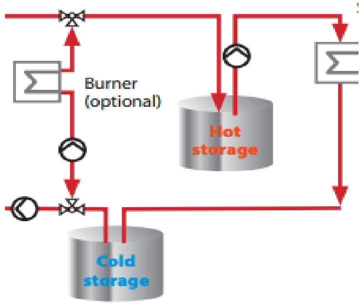
## STEP




+ Competitive cost
+ Mature Technology
+ Several hours of storage

- Limited potential
- Long development time

## Thermal Storage




+ Modular storage
+ Several hours of storage

- Limited maturity

## Batteries

+ Modular storage
+ Several hours of storage

- Cost decreasing continuously
- Limited large-scale maturity

## Green Hydrogen

+ Seasonal storage

- Limited maturity
- Green hydrogen more competitive in industrial uses

Analyze for each new base plant :

- The final impact on the cost taking into account a possible strong development of PV and wind power,
- Ensure that there is no storage solution that can guarantee the same uses with a lower cost of kWh at the national level

masen

Ministerio de Energía

Gobierno de Chile

# Chilean power system and the National Green Hydrogen Strategy

## Customizing Business Cases to Country Context and Needs

July, 2021

**Felipe Verástegui Grünewald**, Green Hydrogen Specialist, New Energy Carriers Unit, Chilean Ministry of Energy

# Chile is a country with abundant renewable

## Renewable energy potential (GW)

*Source: Ministry of Energy*


587 GW
Concentrated solar power

879 GW
Solar photovoltaic

15
Run of river hydro

295 GW
On-shore wind

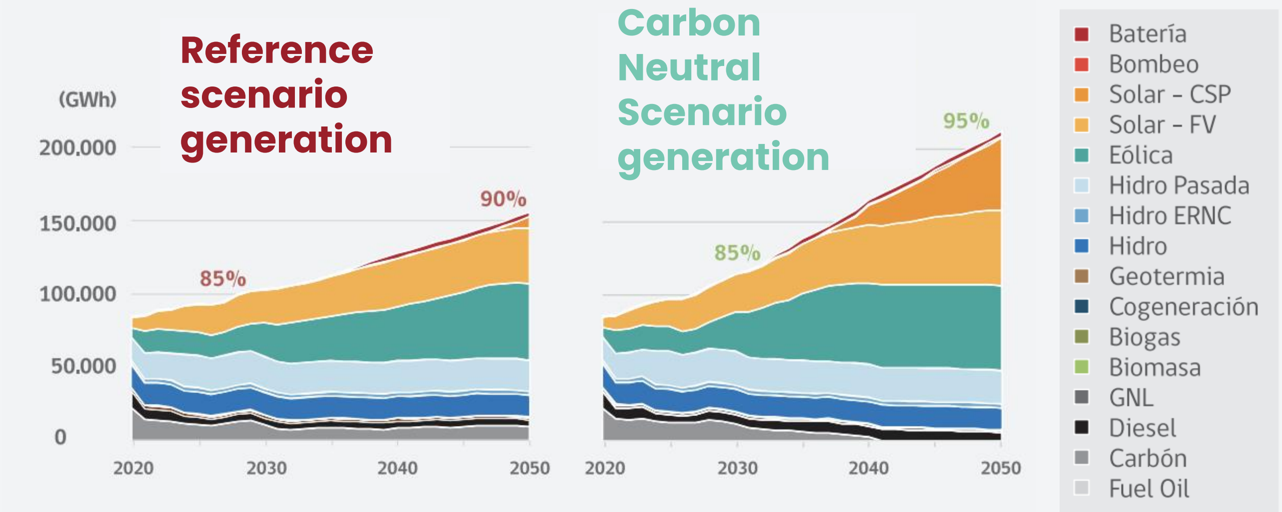
## Some long-term goals and key initiatives

We are **phasing out all coal power plants** by 2040. 50% will close by 2025.

We are redesigning our energy, ancillary services and capacity markets through the deployment of a **Flexibility Strategy.**

We are committed to achieve **carbon neutrality** by 2050. A framework law giving legal support is being implemented.

We are pursuing **electrification and decarbonization goals** in transport, heating, and other end uses.



# Chilean National Green Hydrogen Strategy

## Mid-term H2 goals

**2025**

**5** BUSD — Top destination for green hydrogen investment in LATAM

**5** GW — Electrolysis capacity operating and under development

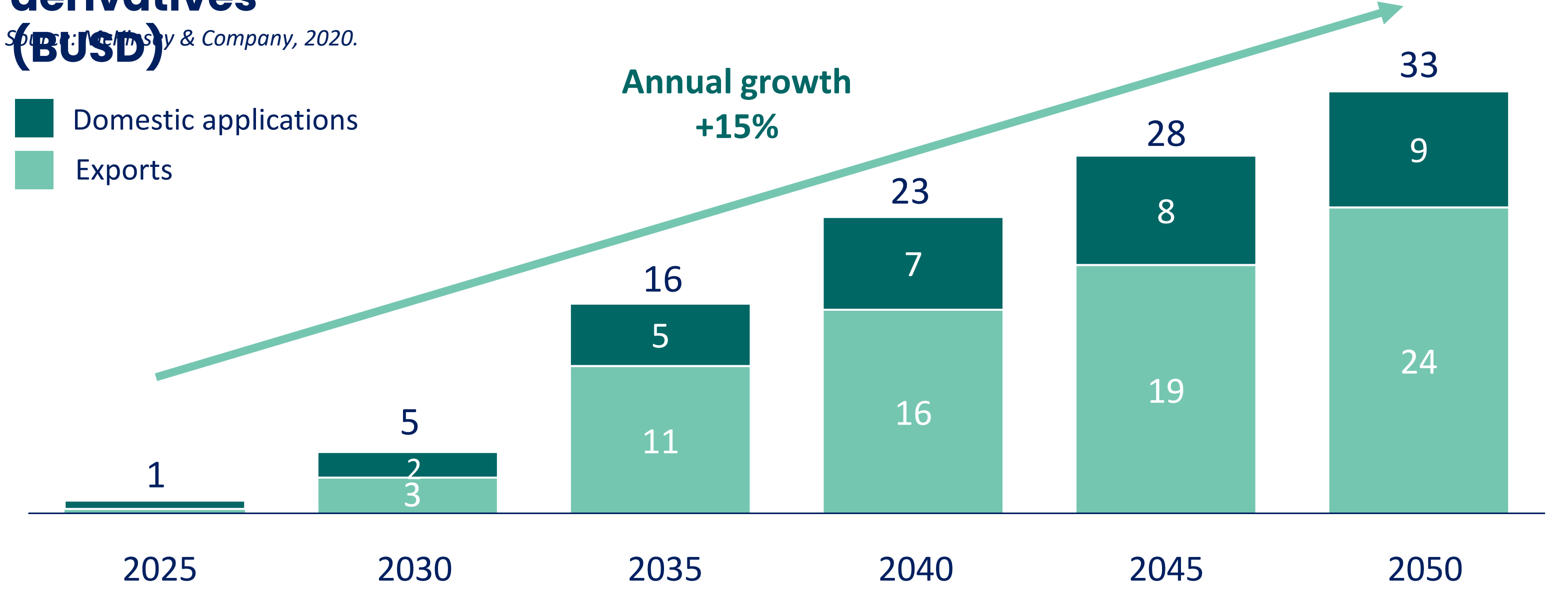
**200** kton/year — Production in at least 2 *hydrogen valleys* in Chile

## Prioritized lines of action and projected market size

1. Regulation and permits
2. Finance and incentives
3. Domestic market and international partnerships
4. Local value

### Projection of the Chilean market size for green hydrogen and derivatives (BUSD)

*Source: McKinsey & Company, 2020.*




| | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|
| Renewable associated capacity (GW) | 5-8 | 40 | 145 | 200 | 250 | 300 |
| Required cumulative investment (BUSD) | 8 | 45 | 150 | 220 | 270 | 330 |

# Framing the challenges and opportunities

## Policy initiatives and long-term goals

- NDC – Carbon Neutrality in the Energy Sector.
- Long-Term Energy Planning
- National Green Hydrogen Strategy.
- Electromobility Strategy
- Heating & Cooling Strategy
- Flexibility Strategy
- Tributary Instruments Strategy (*)
- Law Bill for H2 Quotas (*)

## National Electric System

- +98,5% of the population
- +35.000 km in transmission lines
- 80.000 GWh yearly generation
- 47% renewable share in 2020
- 130% growth in PV and wind over the last 5

## Medium-sized systems

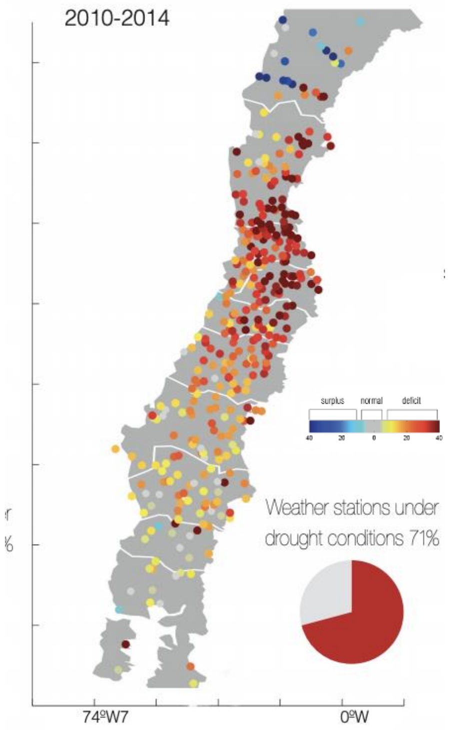


- Stand-alone systems from 1.5 to 200 MW in installed capacity.
- Currently include 9 individual systems, located mainly in the south.
- Generation is mainly diesel and gas based, with complements from wind and hydro power

## Isolated systems

- Stand-alone systems smaller than 1.5 MW in installed capacity.
- Currently include +100 small systems throughout the country, providing supply for +15.000 people.
- Generation is mainly diesel, with complements from PV and wind

## Climate change trends and potential impacts




## Green hydrogen integration

- Requires large amounts of renewable electricity
- Provides an opportunity for long duration or seasonal storage
- May provide energy and or grid services
- May provide demand side flexibility
- Provides an opportunity for sector coupling in isolated systems

## Other socioeconomic and environmental challenges

- Energy poverty
- Local pollution and air quality
- Social opposition to large scale transmission projects
- Sustainable recovery needs and local development

Ministerio de Energía

Gobierno de Chile

# Chilean power system and the National Green Hydrogen Strategy

Customizing Business Cases to Country Context and Needs

July, 2021

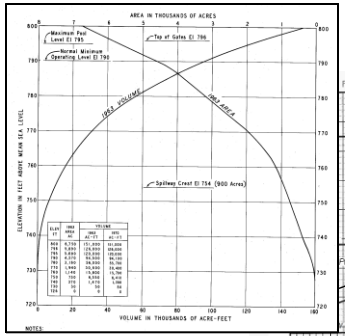
# Hydropower as Energy Storage

Brennan Smith
Water Power Program Manager
Oak Ridge National Laboratory

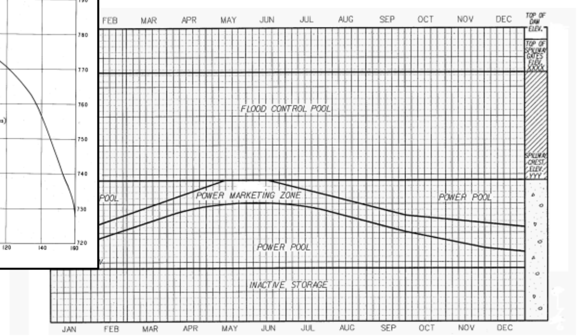
14-July-2021

# Hydropower is Energy Storage

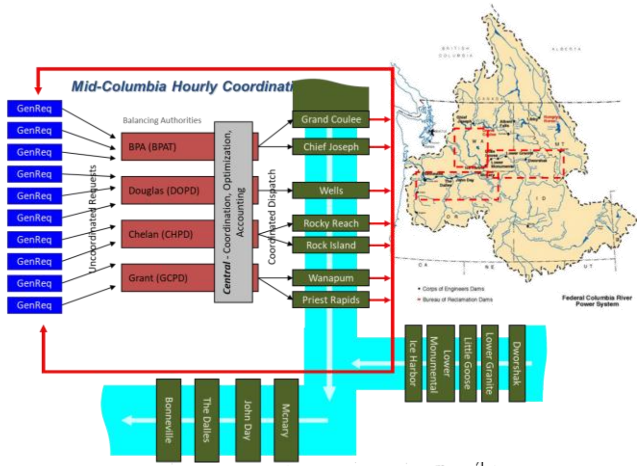
- All hydropower facilities store energy and water.
  - The issue is when, for how long, and how much
- Hydropower storage (and flexibility and value) has two sources of constraints.
  1. Environmental interactions with and competing water uses for the local facility
     - constrains MW (power) and MW/min (ramping)
  2. The river-systemic context for the facility - it cannot function in isolation
     - constrains volume / flow = residence time
- Head (elevation change of the flowing water) is the primary site characteristic that determines cost.

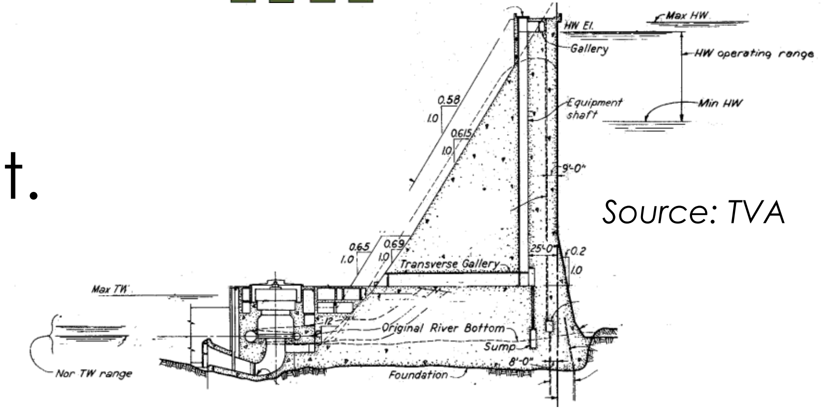



Source: TVA




Source: US Army Corps of Engineers

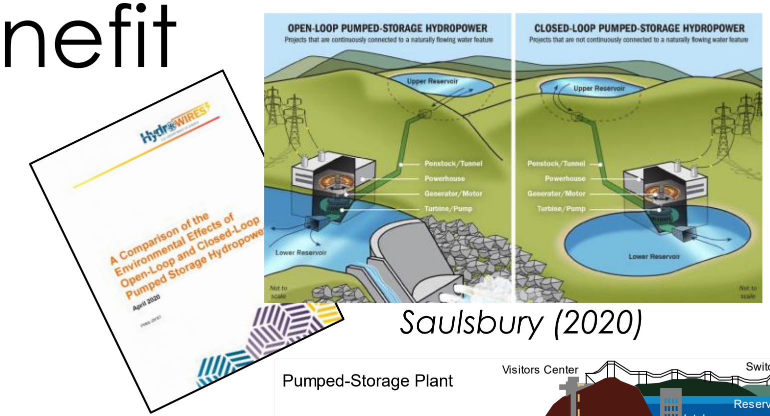


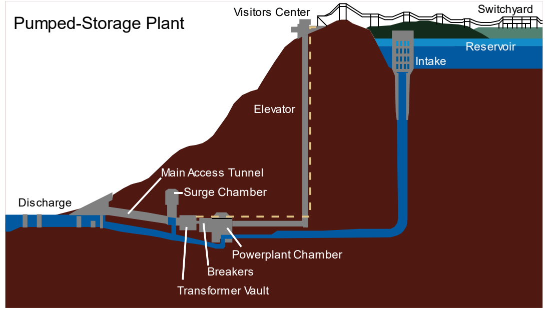

Source: TVA

# Pumped-Storage Technology Cost-Benefit

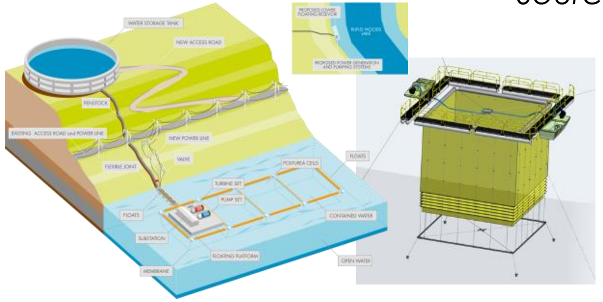
- Open loop or closed loop
  - Closed-loop removes many (not all) systemic water use and local environmental issues
- Site, reservoir, and conveyance options
  - L / H minimization to manage cost, risk
  - Scale of benefits:  power x residence time
  - Advanced technology for tunnel, penstock
- Powerhouse technology
  - Integrated pump-turbine, tertiary designs, variable speed – these influence flexibility and services
  - Emerging technology:  modularity and reduced costs per MW, MWh



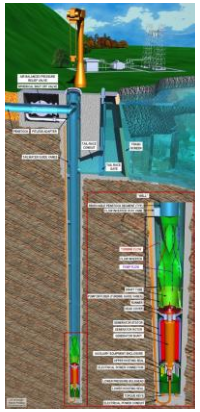

*Saulsbury (2020)*



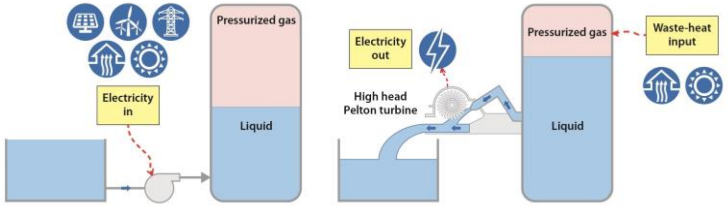

*Source: TVA*



*Source: ORNL & Shell Energy NA*



*Source: Obermeyer Hydro*




*Source: ORNL (GLIDES)*

# Breakout Session 2: Long Duration and Utility-Scale Storage

**Moderator:**

Tim Larson,
*Ross Strategic*

**Abderrahim Jamrani**, Engineering Director, Masen (Moroccan Agency for Solar Energy): *Focus on Morocco project combining concentrated solar power (CSP) and thermal energy storage*

**Felipe Verástegui Grünewald**, Green Hydrogen Specialist, New Energy Carriers Unit, Chilean Ministry of Energy: *Focus on Chile's National Green Hydrogen Strategy*

**Brennan T. Smith**, Water Power Program Manager, Oak Ridge National Laboratory. *Focus on pumped hydropower storage*

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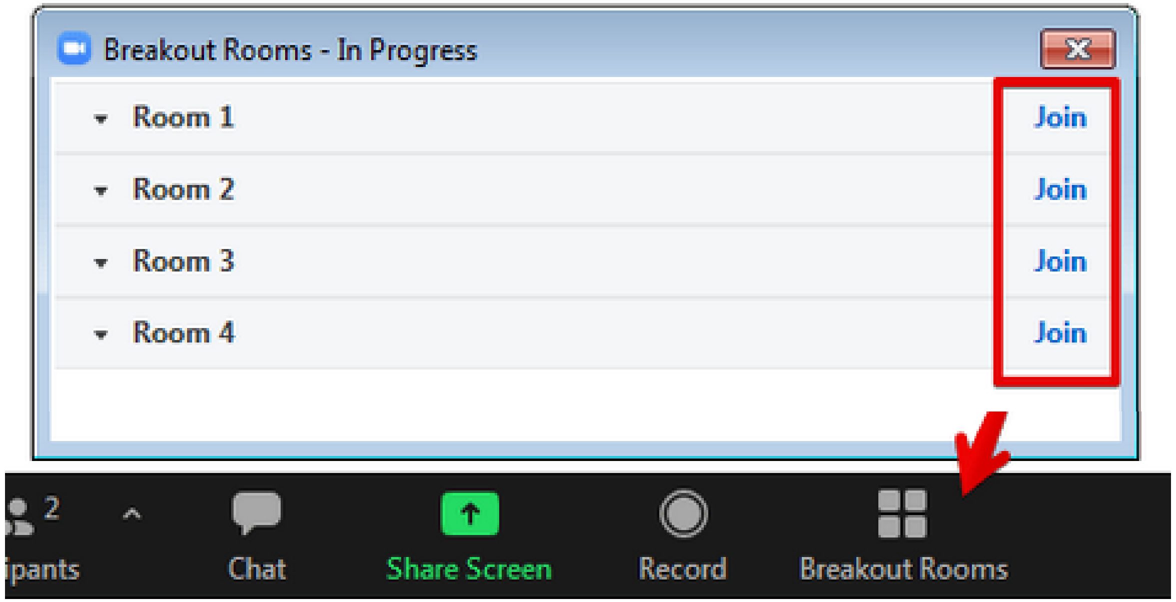
# Please Join One of the Following Breakout Rooms

**Room 1: Battery Storage**

**Room 2: Long Duration and Utility-Scale Storage**

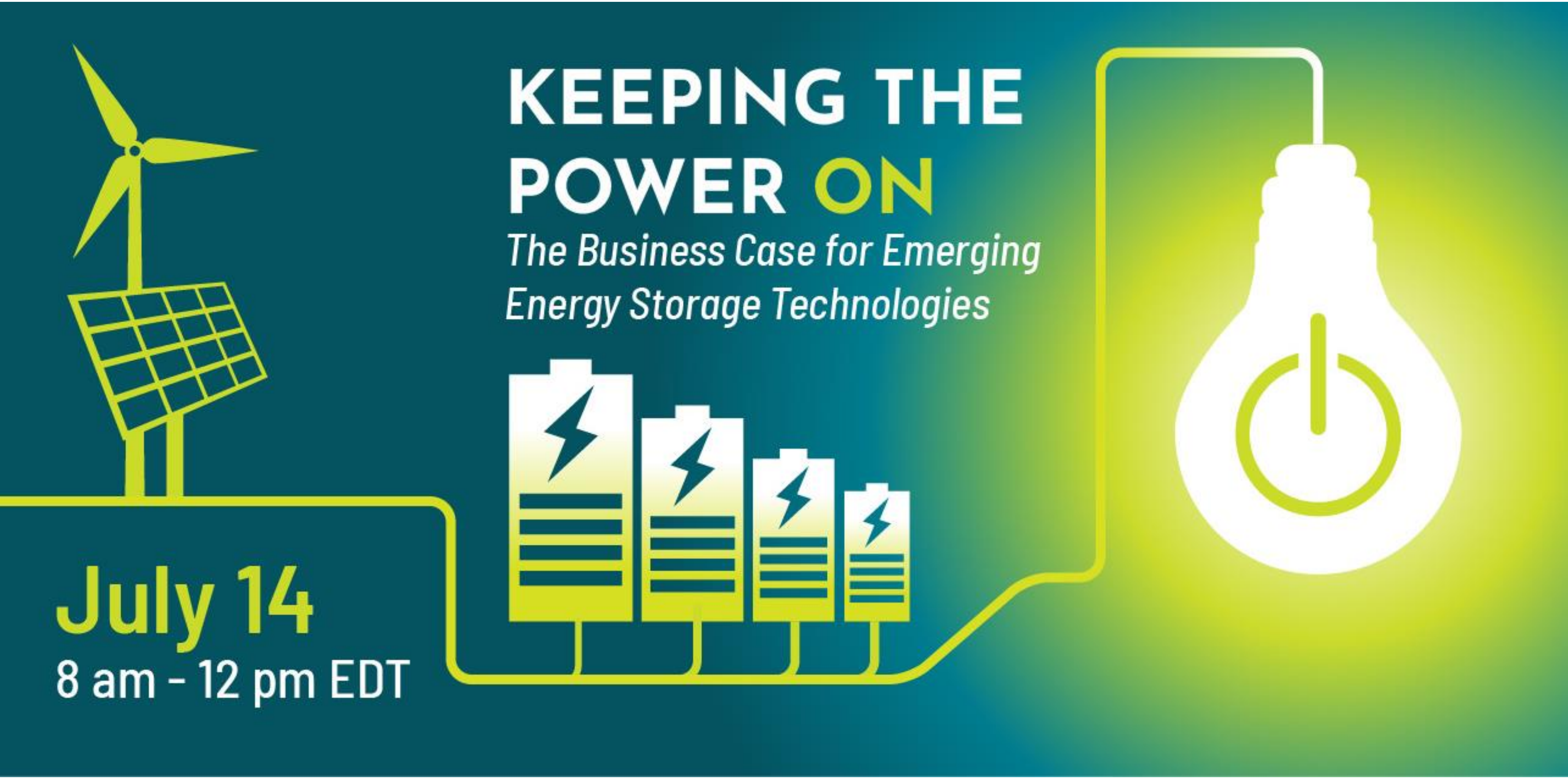
- To select a room:
  - Click **Breakout Rooms**
  - Hover over the room of your choice and click **Join**
  - You can also navigate between rooms using the same controls



# Breakout Sessions: Customizing Business Cases to Country Context and Needs

# Final Remarks

**Daniel Morris**, Clean Energy Lead, Climate Investment Funds


KEEPING THE POWER ON
The Business Case for Emerging Energy Storage Technologies
July 14
8 am - 12 pm EDT