Integrating Solar PVs and Storage in Singapore’s Long-term Energy Portfolio

Liu Yang
Senior Research Fellow
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System integration is essential

- An integrated policy, market design, and business models

Source: IEA (2017)
More renewables, more flexibility

- Turn intermittent energy into baseload power with support of flexible capacity

The future is distributed

- Policy objectives and technology progress drive distributed energy resources

Decentralization ratio = ratio of non-grid-scale capacity to total installed capacity
Source: Bloomberg New Energy Finance
Singapore’s energy transition

- Centralized natural gas power system (13 GW) + 2000 distributed small scale solar sites (240 MW) in 2017
- Anticipative regulation on intermittency and storage technologies
- Full retail contestability in the electricity market

Source: EMA (www.ema.gov.sg)
Nordic experience from central to distributed generation

- Denmark’s energy transition: CHP heat/power + decentralised solutions

Source: Energinet
However, Singapore faces challenges

- LCOE of solar PV has reached grid parity compared with electricity tariffs, but
- **Intermittency**: the risk of a solar PV project is higher than a CCGT project

![Solar Irradiation at 1 minute resolution](image)

Source: Data from the National Environment Agency

![VaR (S$/MWh)](image)

Source: Energy Studies Institute, NUS

- With a portfolio approach of power asset investment, 20% to 30% of solar PV share is optimum for a CCGT power plant to reduce the risk and to optimise the profit
Can storage help?

- **Arbitrage value**: shift electricity from periods with low marginal generation costs to periods with higher costs
- If we only consider arbitrage benefits from peak and off-peak price, storage does not contribute to improving the risk profile of solar asset

Source: Energy Studies Institute, NUS
Why is the market new?

➢ So far …

SUPPLY = DEMAND

While, with flexible capacity…

SUPPLY ≠ DEMAND
Focus on the broader, overall system value or customer value?

- Rewarding flexible capacity requires a detailed analysis of the various value components.

<table>
<thead>
<tr>
<th>Energy services</th>
<th>Avoided capacity</th>
<th>Grid Support</th>
<th>Financial</th>
<th>Additional benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>Generation</td>
<td>Reactive power</td>
<td>Fuel price hedge</td>
<td>Grid security</td>
</tr>
<tr>
<td>Transmission and distribution</td>
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<td>Voltage control</td>
<td>Market price</td>
<td>Environmental/ carbon emissions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Frequency support</td>
<td></td>
<td>Socio-economic development</td>
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<td></td>
<td></td>
<td>Operating reserves</td>
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Source: IEA, 2017
Assessing the system value of storage

- **Balancing value**
  Provision of balancing reserves

- **Capacity value**
  Substitute peak capacity

- **Renewable energy integration**
  Avoid renewables curtailment
Demand response enabling system wide flexibility

- Ability to shift demand = ability to reduce or avoid costs (Global demand response programmes can provide 185 GW of flexibility and avoid USD 270 billion of investment in new electricity infrastructure.)

Source: IEA (2017)
Scenario analysis for high integration of flexible loads and renewables in Singapore

Model framework

- The ESI team calibrates an electricity dispatch and investment evaluation model with the cost-minimization objective
- Model electricity dispatch and long-term green-field investment in the power system
- Minimize total system costs over 8760 hours of a full year
- Incorporate mainstream flexible options including EES technologies, DSM technologies (load curtailment and shift), and renewables
- Build on an open-source model in collaboration with DIW Berlin.

Key outcome

- Energy mix
- System cost
- System value
Installed capacity

- Solar capacity: 2 GW in 2025, 10 GW in 2035, and 29 GW in 2050.
- Storage capacity: 240 MW in 2025, 1200 MW in 2035, and 6480 MW in 2050.
- The E/P ratio of storage is around 1 hour in 2025 and 2035, and around 5 hour in 2050.
Share of solar energy can increase to 5% with the target of 2 GW in 2020, to around 19% with technical maximum solar installation of 10 GW in 2035, to around 44% in 2050 if the capacity constraint is released.
Storage and demand response

- Storage is used in all scenarios, with share of storage in the dispatched electricity being small at < 1%

Usage of storage and demand side flexibility over week 1st Jan to 7th Jan in 2035
System value of storage for high shares of solar energy

- The share of solar capacity in total capacity mix remains comparable with scenarios “no storage”, “baseline” and “max storage” in 2035, however
- **The system value** is around 1% of the total electricity system costs, equivalent to SG $100 million
Marginal cost of electricity generation

- Average marginal generation cost on a yearly basis:
  - 9 SG$ cents/KWh for 2025 scenario and 10 SG$ cents /KWh for 2035 scenario
  - 15 SG$ cents/KWh for 2050 scenario
New roles for market participants

- Provide energy services beyond electricity as a commodity

- Production (3rd Party Access)
  - Facilitating trading and balancing

- Transmission
  - Connected platform provider

- Distribution
  - Providing flexibility
  - Managing local power

- Centralized power
  - Cogeneration
  - Renewable energy resources
  - Excess heat
  - Storage
  - Grid operators
    - Thermal network operators (district heating/cooling)

- Distributed asset aggregator/owner
  - Energy system management
  - Resources optimization

- Energy Performance Contract
  - Demand response

Source: own elaboration
Aggregator’s business model

- Rooftop solar leasing + electricity retail + green solutions

  - Rooftop leasing
    - Eg. Microsoft and Sunseap signed agreement on largest-ever 60 MW solar project in Singapore this year.

  - Electricity retail
    - Customise your energy mix with up to 100% clean energy
    - Enjoy up to 20% off your electricity bill

  - Green solution
    - Verification of green electricity via the platform of Tradable Instruments for Global Renewables (TIGRs)
What the future could look like?

- A virtual power plant connects and aggregates distributed energy resources

Source: AGL
What the future could look like?

- A platform for Internet of things connects and manages a wide range of both generation and end-use technologies in order to enable collaboration at the level of households, communities and cities.

Source: EnOSTM platform for Internet of Things (Envision, 2017)
Takeaways

- The share of solar energy in Singapore can increase to around 19% with technical maximum solar installation of 10 GW in an optimal setting.

- The flexibility of conventional generation is still the key factor to integrate renewables, considering its major share in the capacity mix.

- The system value is storage is 1% of the annual system cost, equivalent to SG $100 million.

- The aggregators become a game changer, and the future energy landscape requires an integrated policy, market design, and business models.
Thank you!

Email: Yang_liu@nus.edu.sg
Tel: +65-65161456

National University of Singapore
http://www.esi.nus.edu.sg

29 Heng Mui Keng Terrace
Block A, #10-01
Singapore 119620