

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

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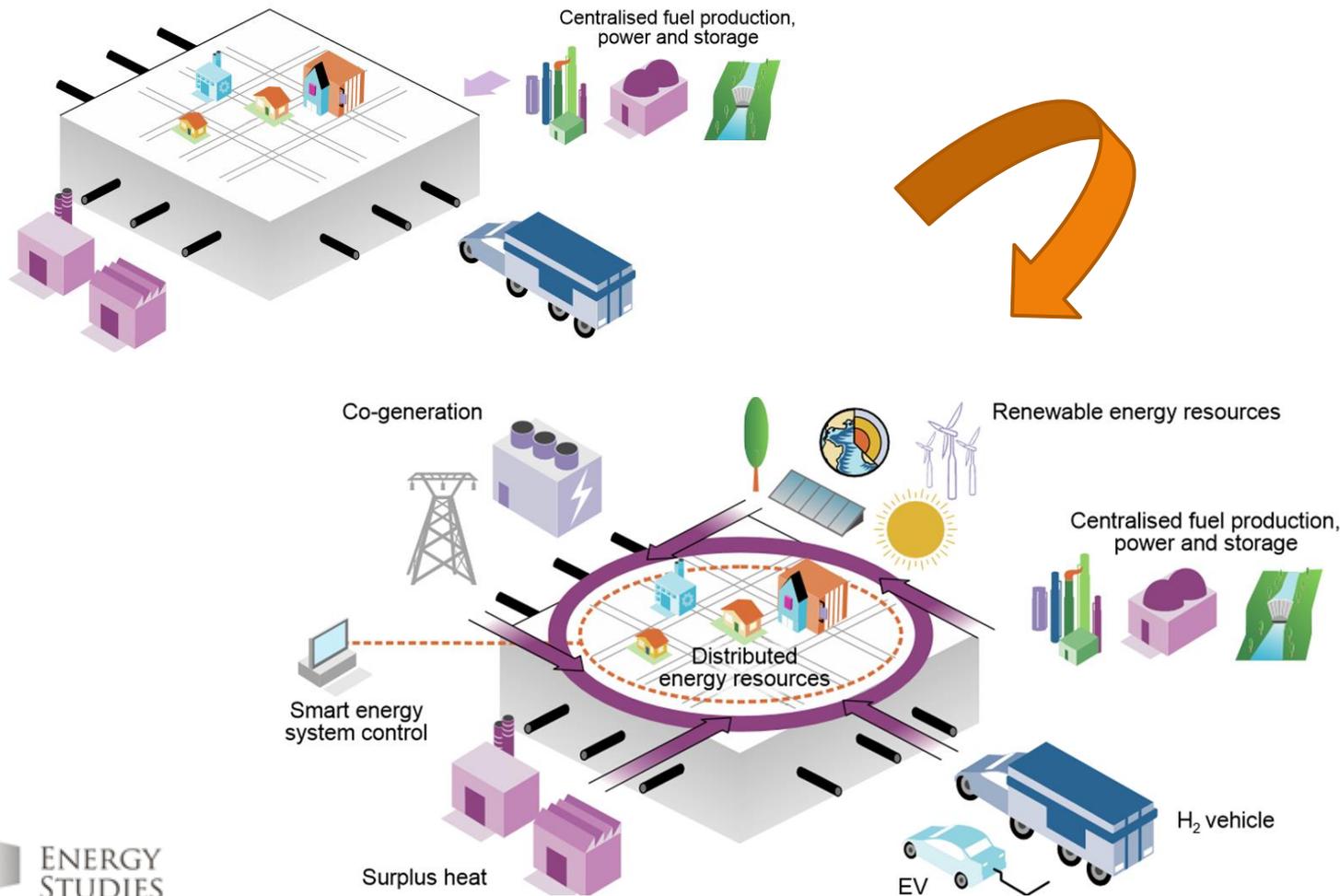
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System integration is essential

- An integrated policy, market design, and business models

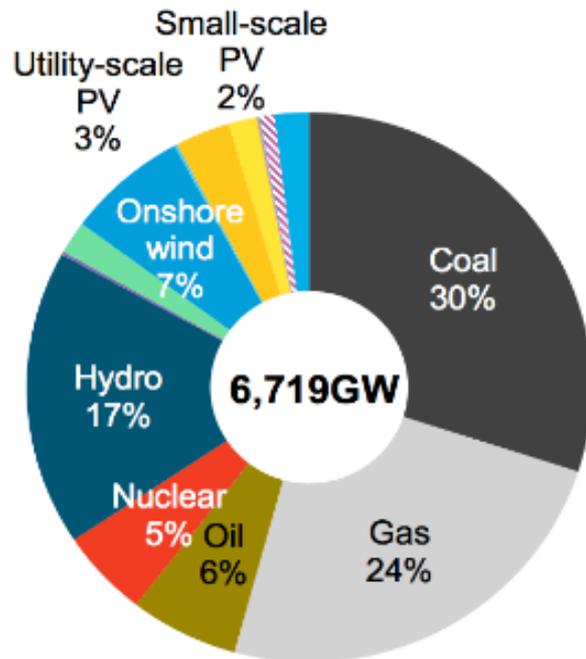


Source: IEA (2017)

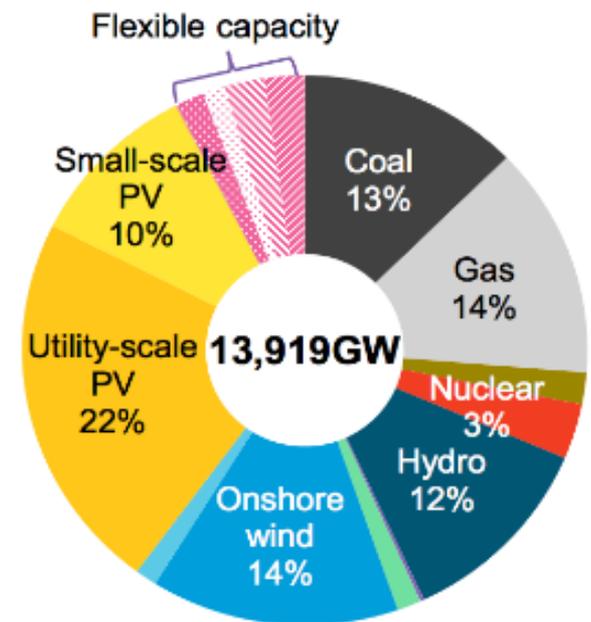
More renewables, more flexibility

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

Global cumulative installed capacity: 2016



Global cumulative installed capacity: 2040

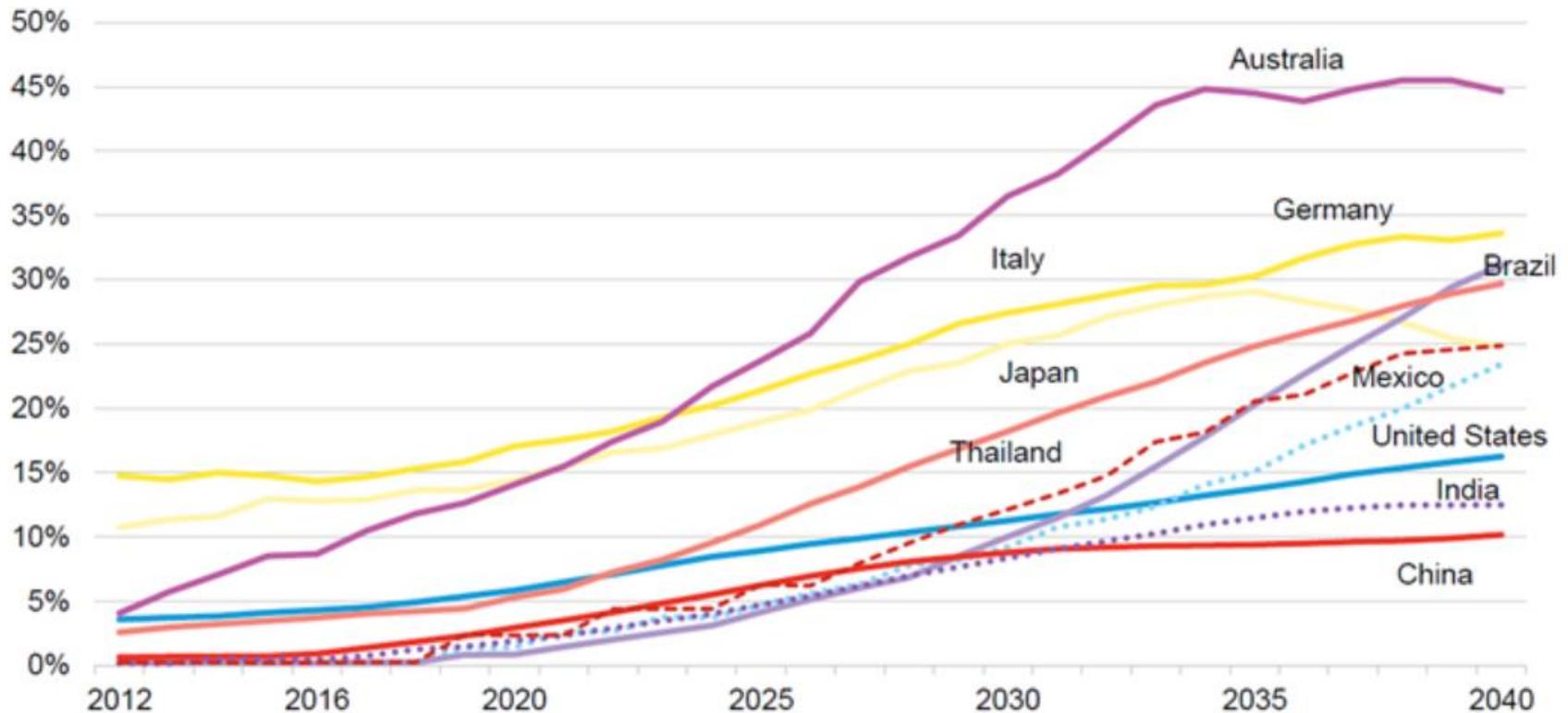


Source: Bloomberg New Energy Outlook (2017)

The future is distributed

- Policy objectives and technology progress drive distributed energy resources

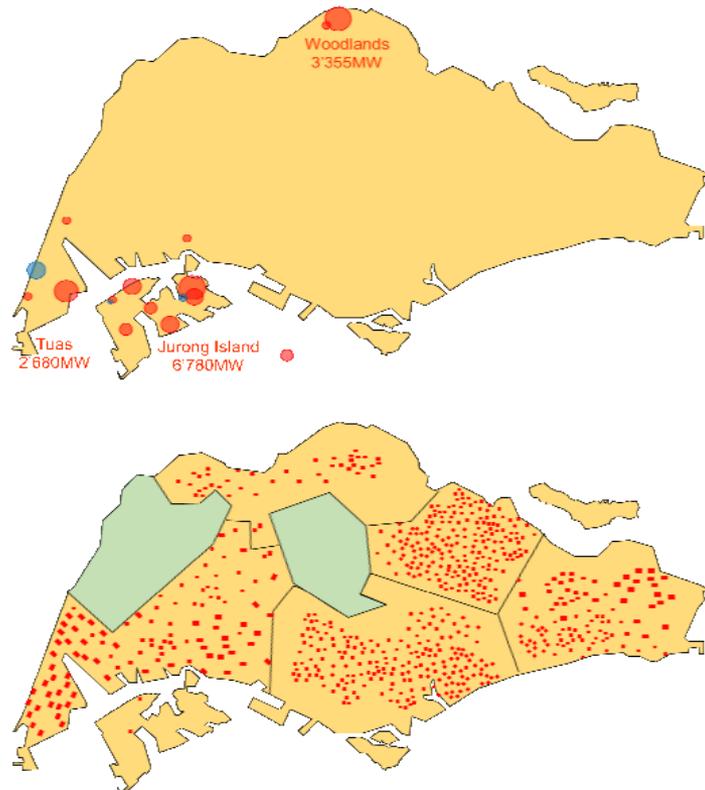
Decentralization ratio



Decentralization ratio = ratio of non-grid-scale capacity to total installed capacity
Source: Bloomberg New Energy Finance

Singapore's energy transition

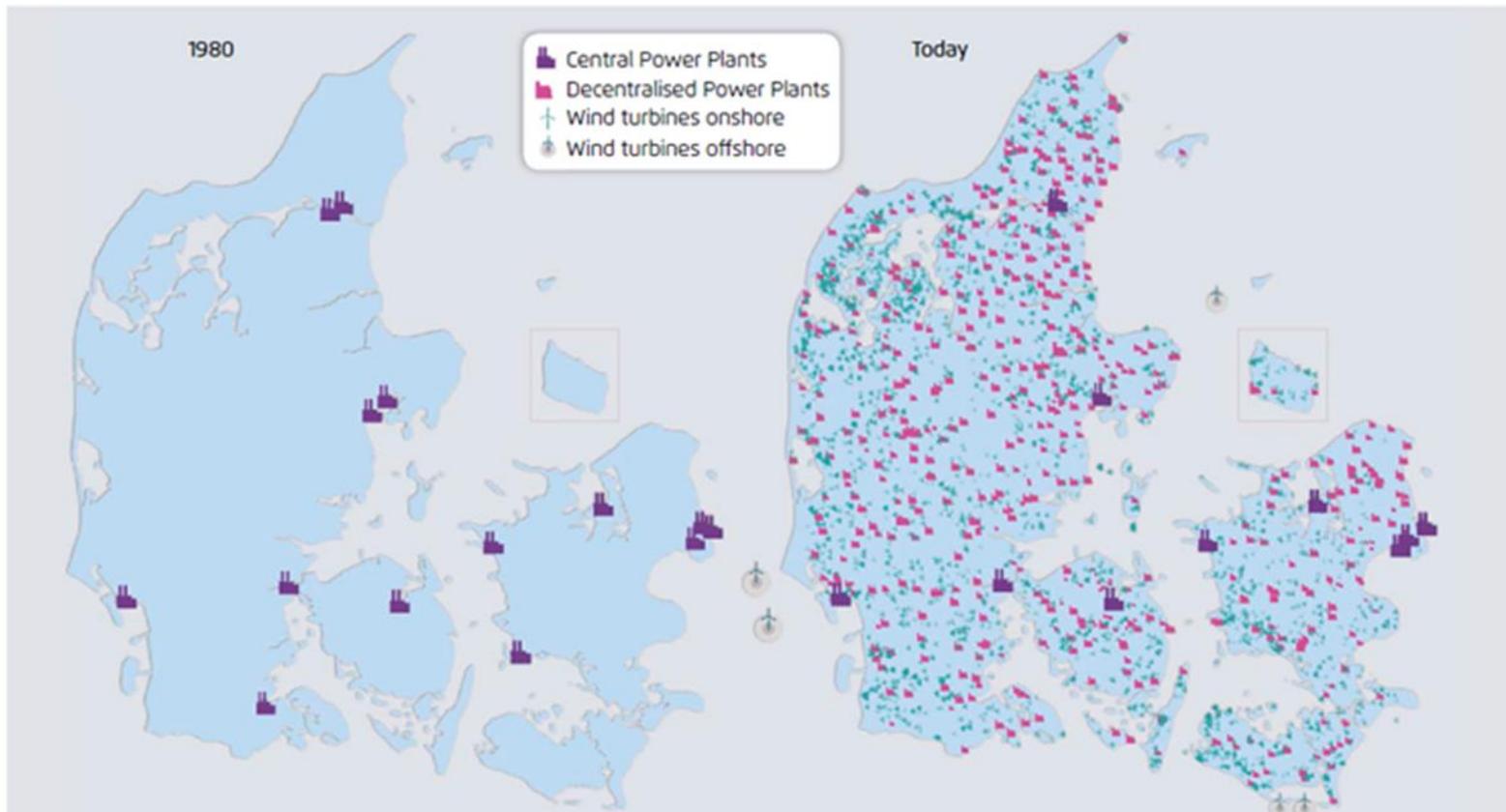
- Centralized natural gas power system (13 GW) + 2 000 distributed small scale solar sites (240 MW) in 2017
- Anticipative regulation on intermittency and storage technologies
- Full retail contestability in the electricity market



Source: EMA (www.ema.gov.sg)

Nordic experience from central to distributed generation

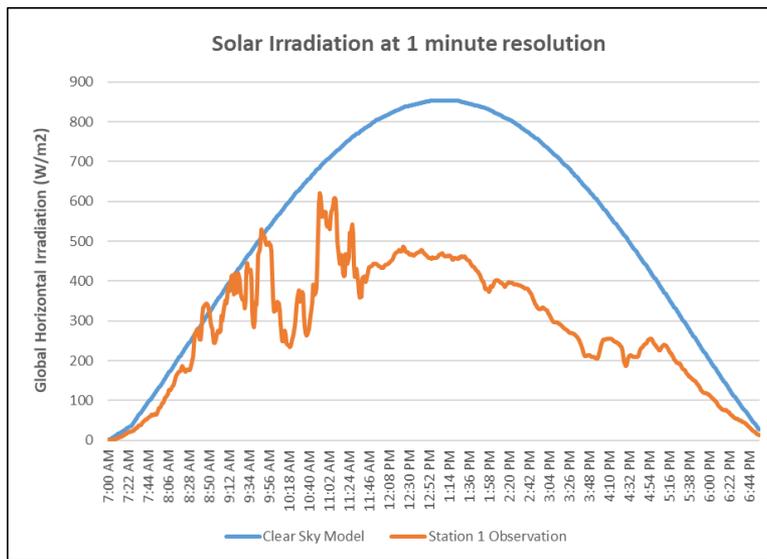
- Denmark's energy transition: CHP heat/power + decentralised solutions



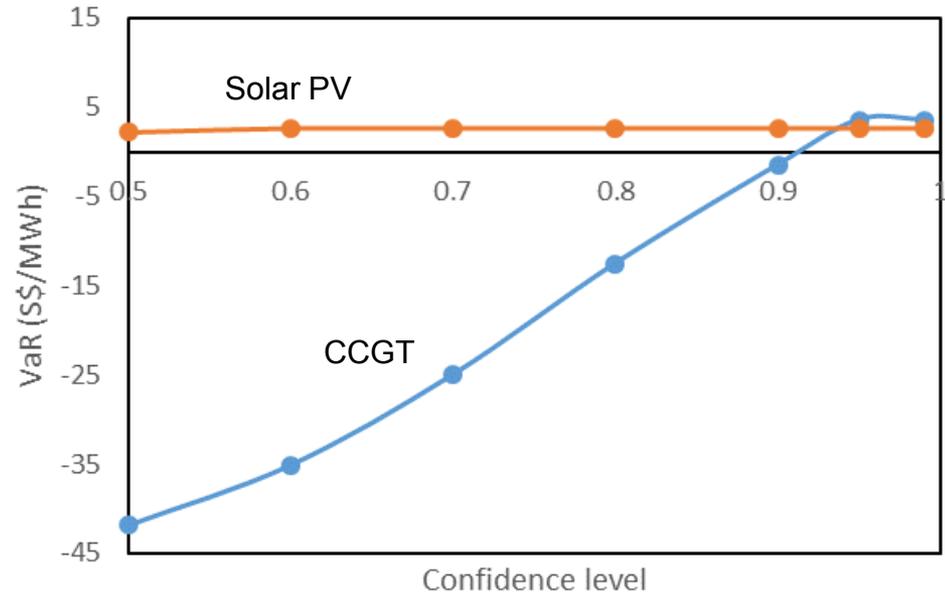
Source: Energinet

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



Source: Data from the National Environment Agency



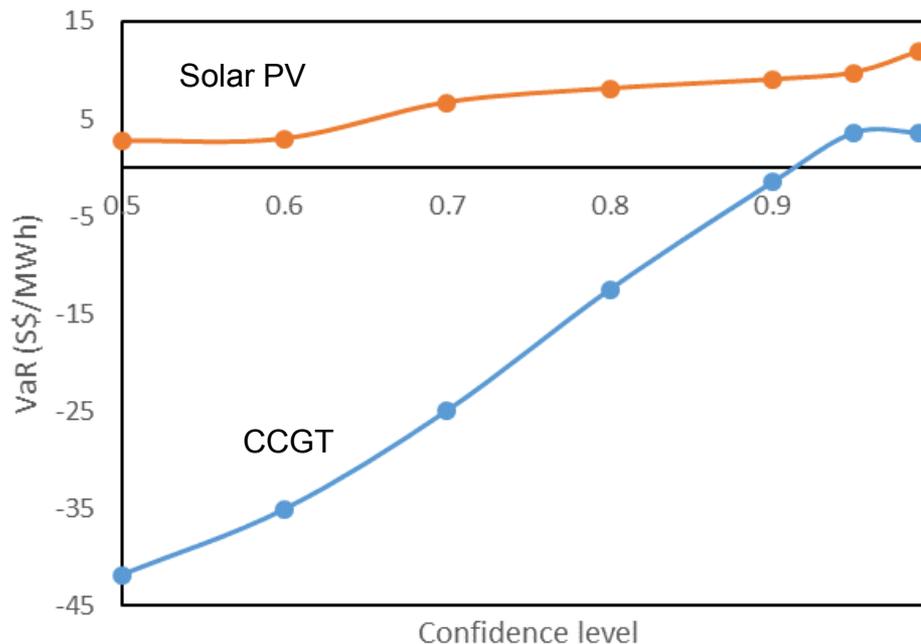
Source: Energy Studies Institute, NUS

- 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

VaR of a CCGT vs. a solar PV power plant with storage



Source: Energy Studies Institute, NUS

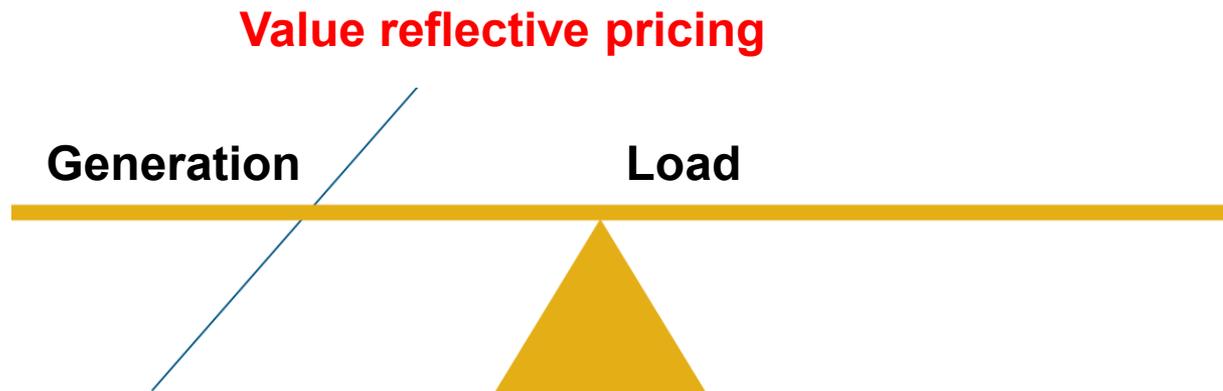
Why is the market new?

➤ So far ...

SUPPLY = DEMAND

While, with flexible capacity...

SUPPLY \neq DEMAND



Focus on the broader, overall system value or customer value?

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

Energy services

- Energy
- Transmission and distribution losses

Avoided capacity

- Generation
- Transmission and distribution

Grid Support

- Reactive power
- Voltage control
- Frequency support
- Operating reserves

Financial

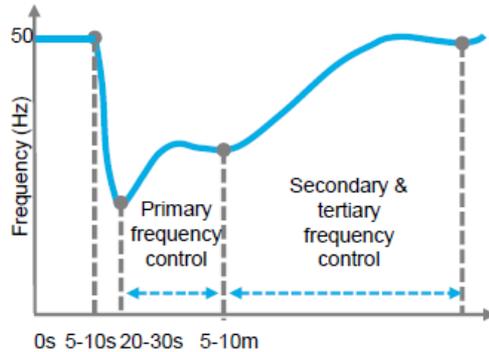
- Fuel price hedge
- Market price

Additional benefits

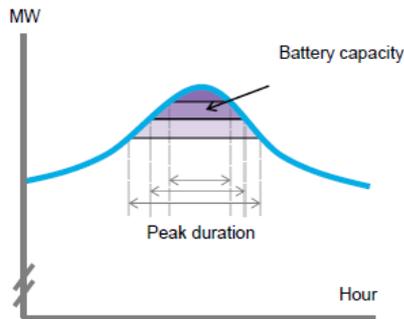
- Grid security
- Environmental/ carbon emissions
- Socio-economic development

Source: IEA, 2017

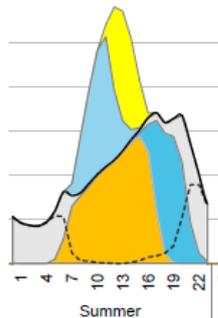
Assessing the system value of storage



- **Balancing value**
Provision of balancing reserves



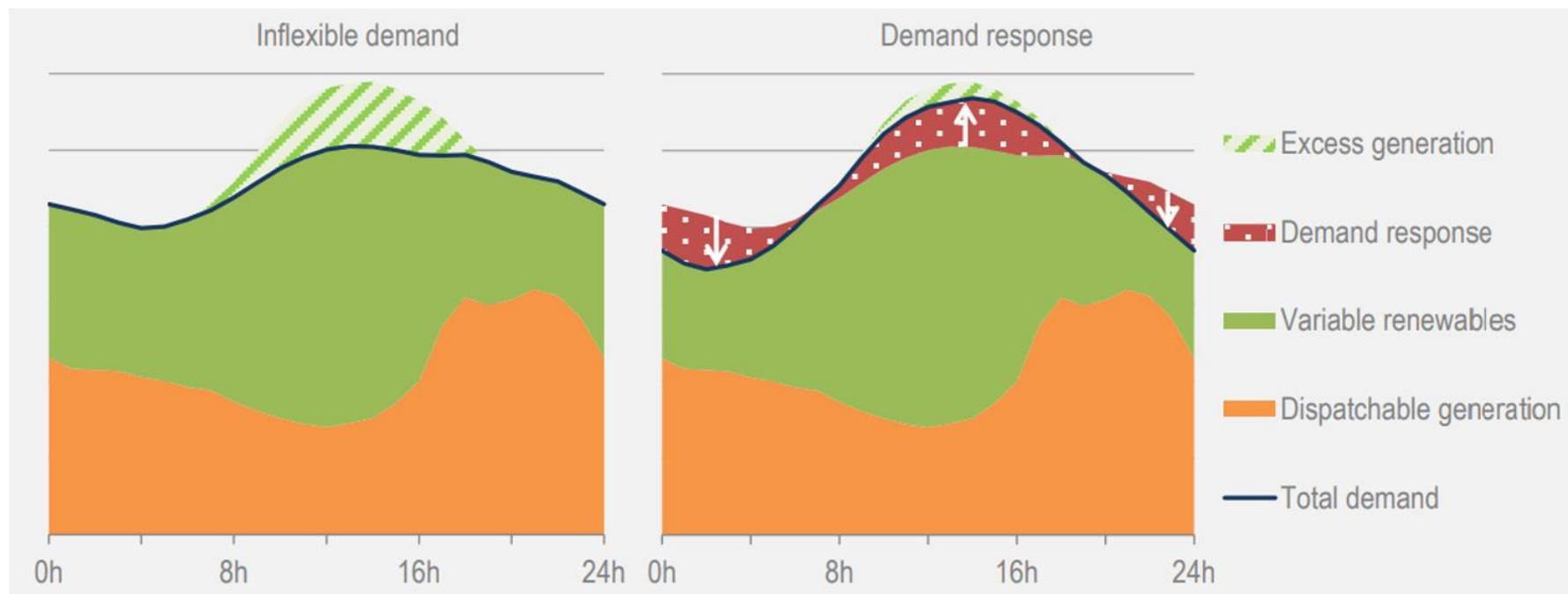
- **Capacity value**
Substitute peak capacity



- **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

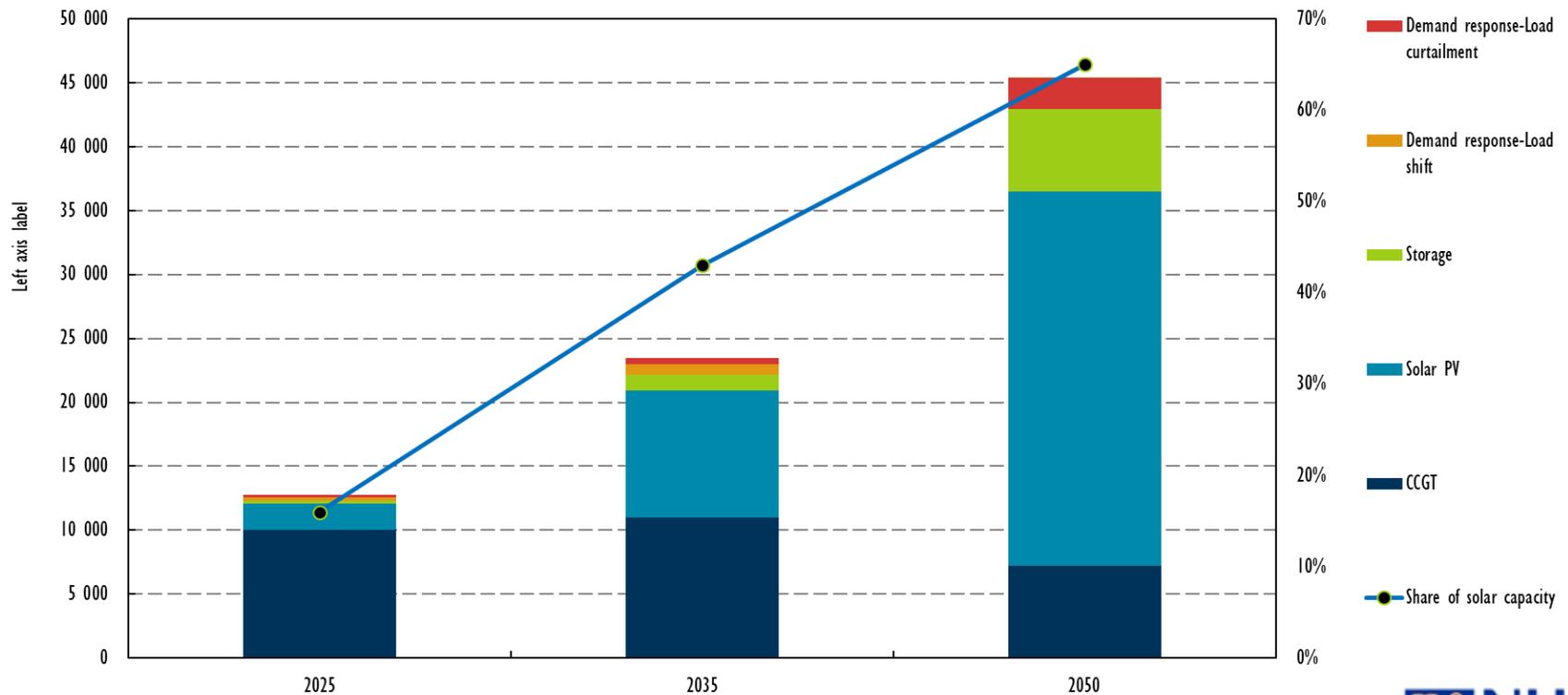
- The ESI team calibrates an electricity dispatch and investment evaluation model with the cost-minimization objective
- Model electricity dispatch and long-term green-field investment in the power system
- Minimize total system costs over 8760 hours of a full year
- Incorporate mainstream flexible options 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

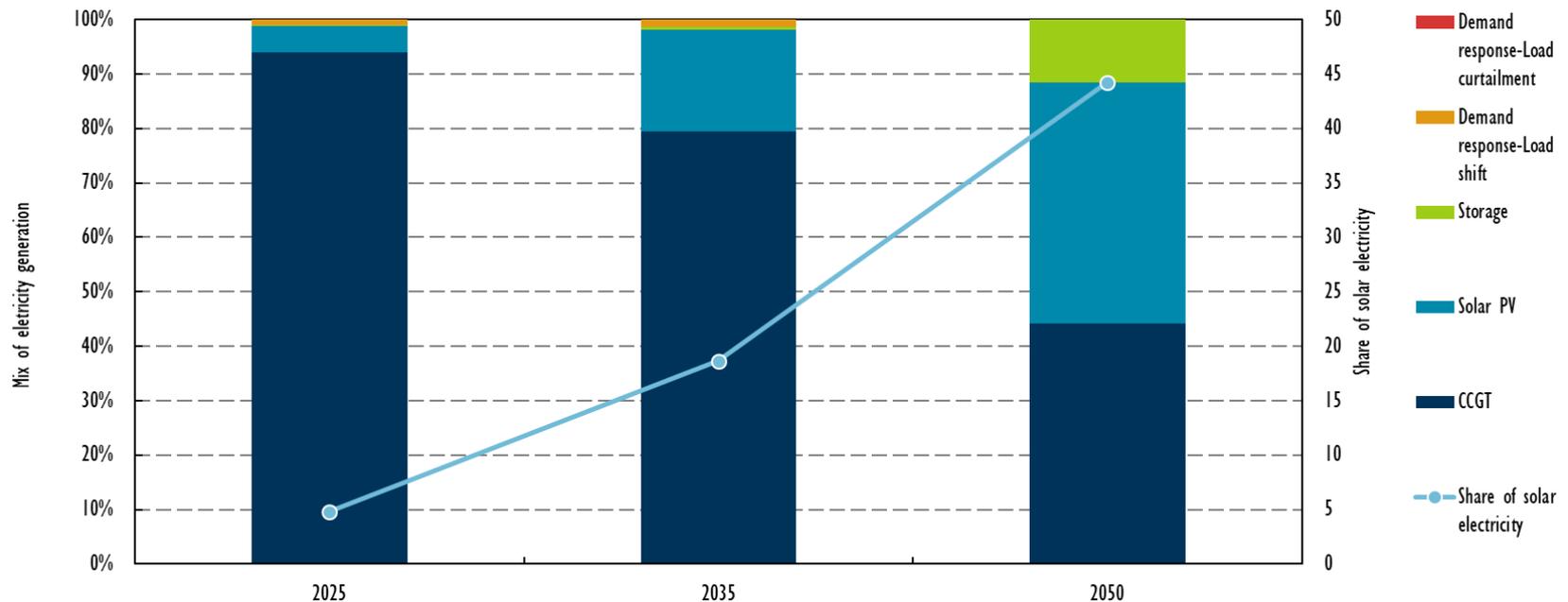
Installed capacity

- 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.



Generation mix

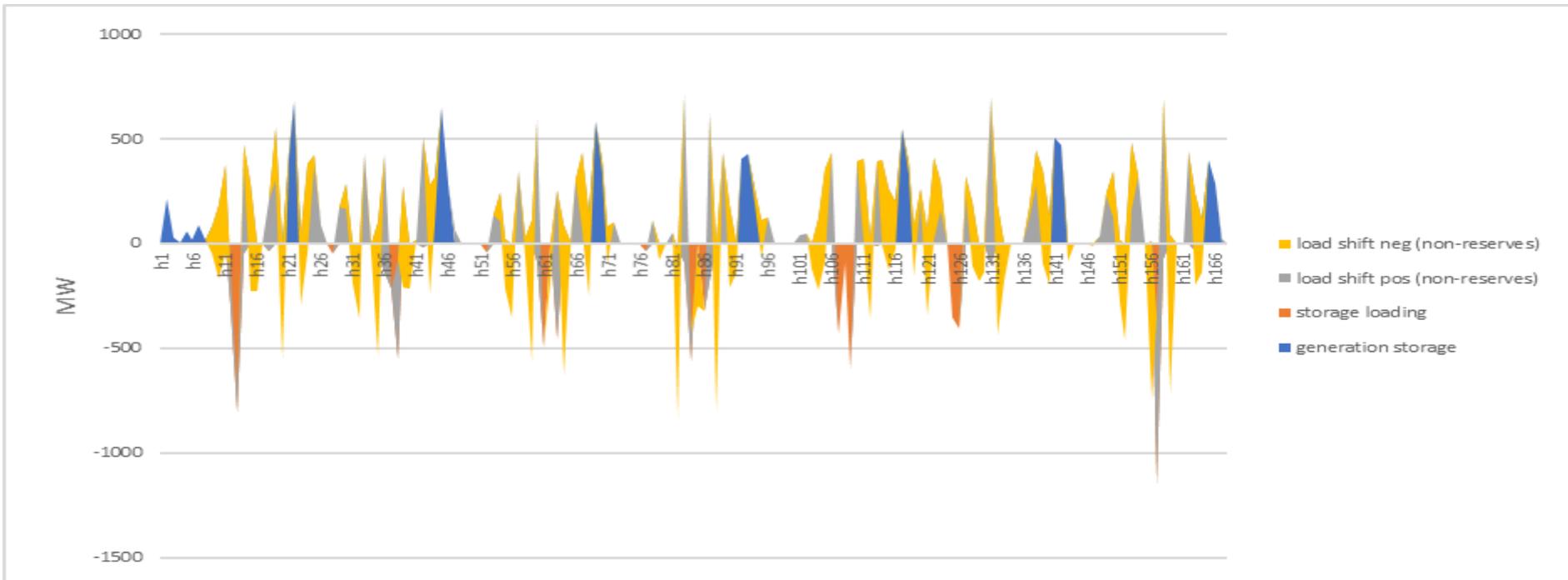
- Share of solar energy can increase to 5% with the target of 2 GW in 2020, to around 19% with technical maximum solar installation of 10 GW in 2035, to around 44% in 2050 if the capacity constraint is released.



Storage and demand response

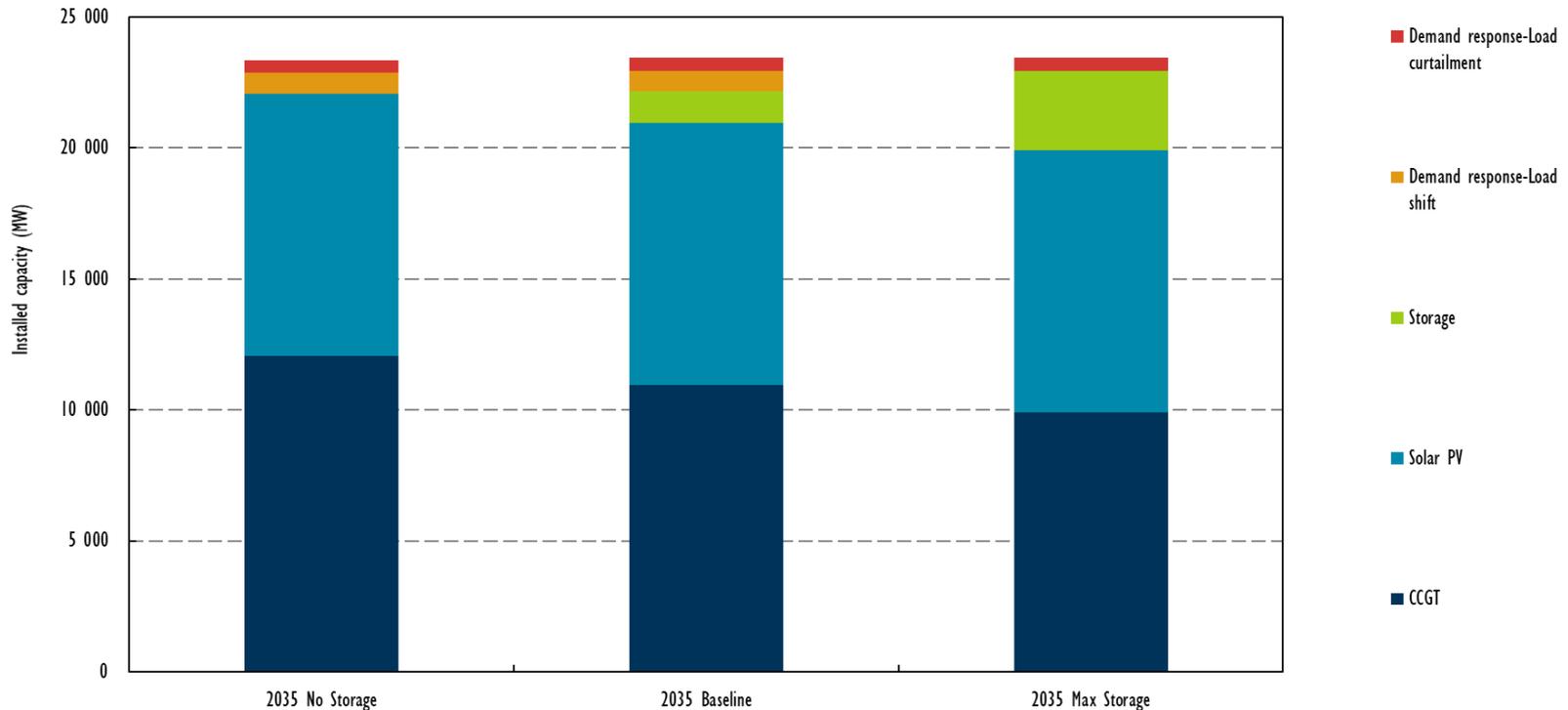
- Storage is used in all scenarios, with share of storage in the dispatched electricity being small at $< 1\%$

Usage of storage and demand side flexibility over week 1st Jan to 7th Jan in 2035



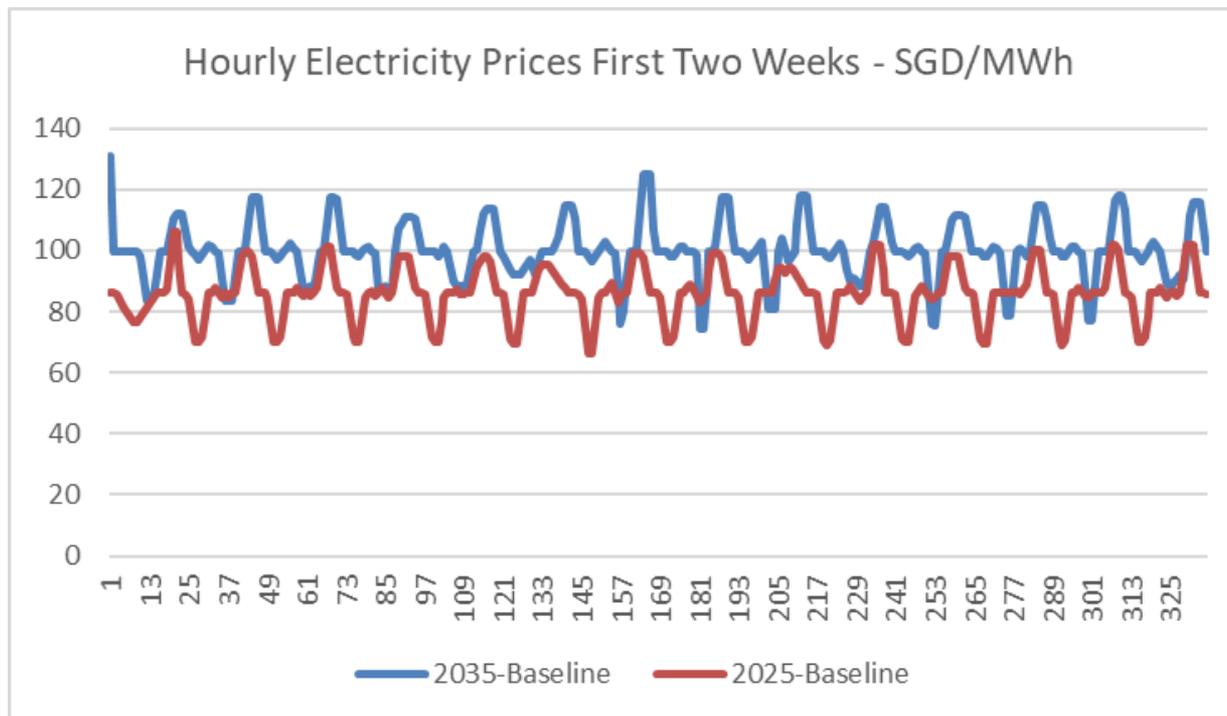
System value of storage for high shares of solar energy

- 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



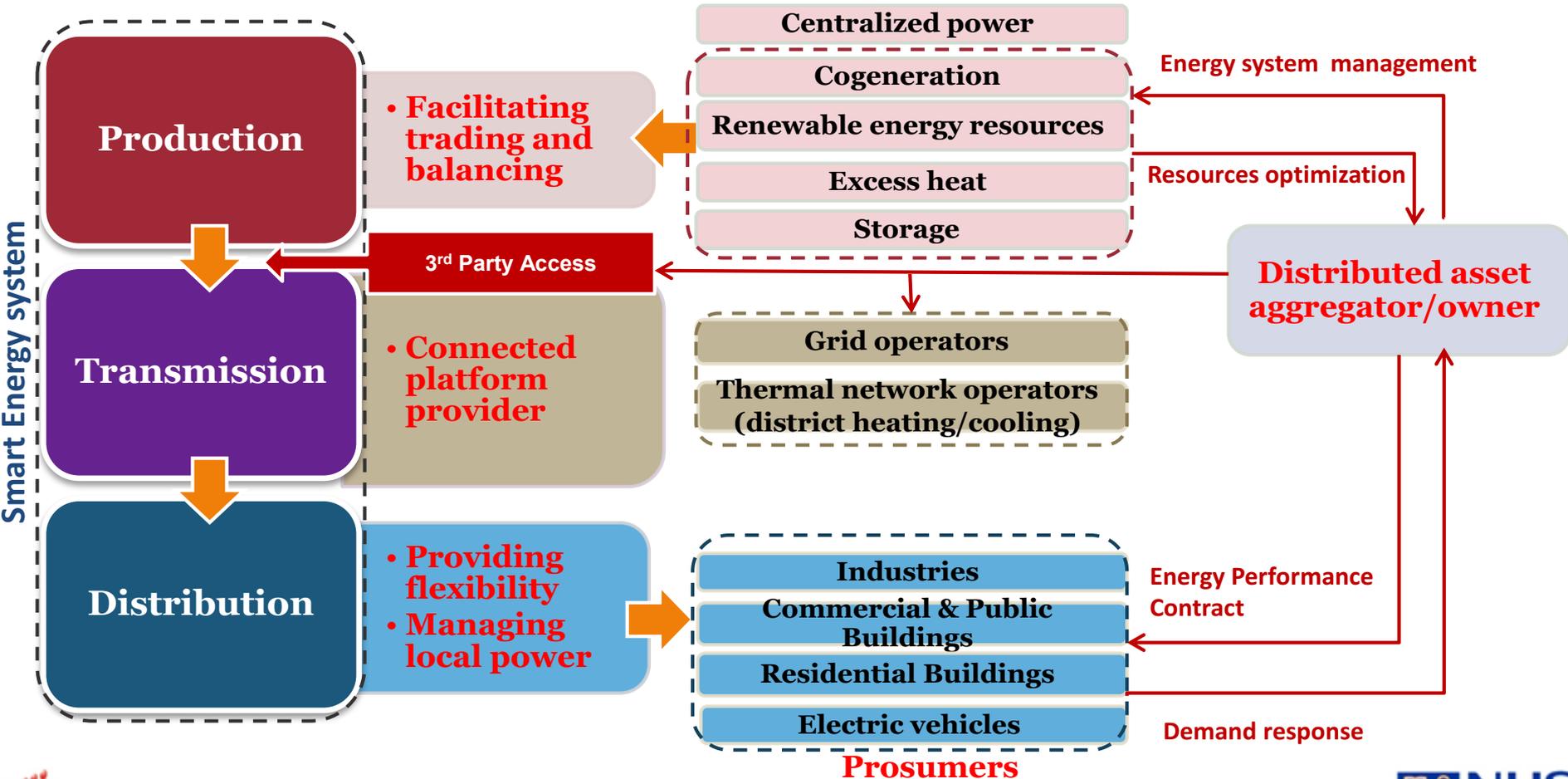
Marginal cost of electricity generation

- 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



Source: own elaboration

Aggregator's business model

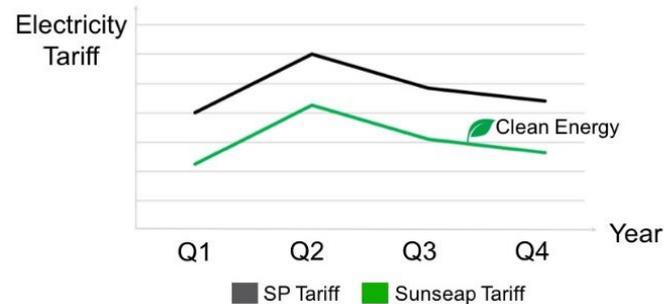
➤ **Rooftop solar leasing + electricity retail+ green solutions**

- *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



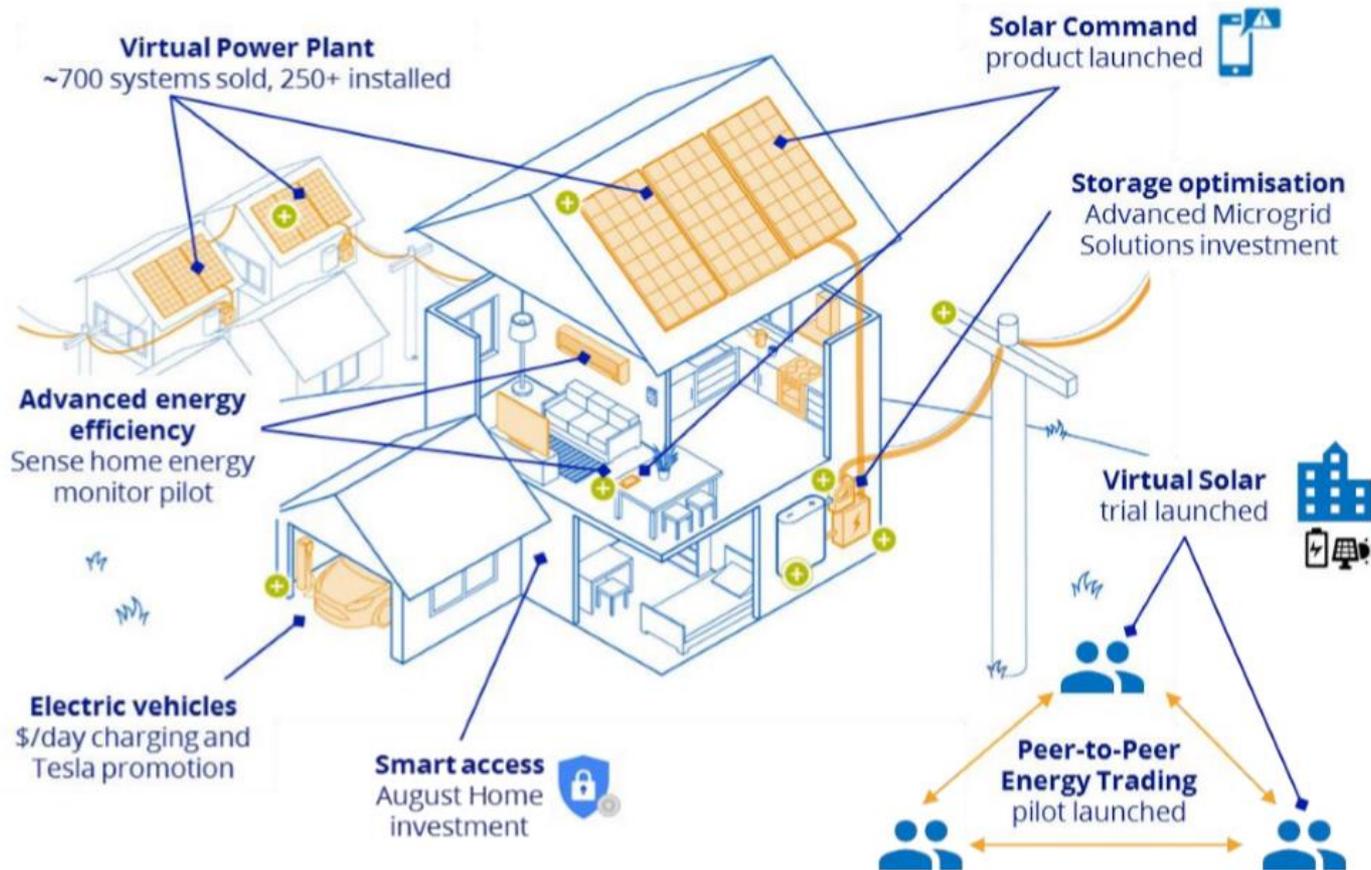
Source: Sunseap

- *Green solution*

- Verification of green electricity via the platform of Tradable Instruments for Global Renewables (TIGRs)

What the future could look like?

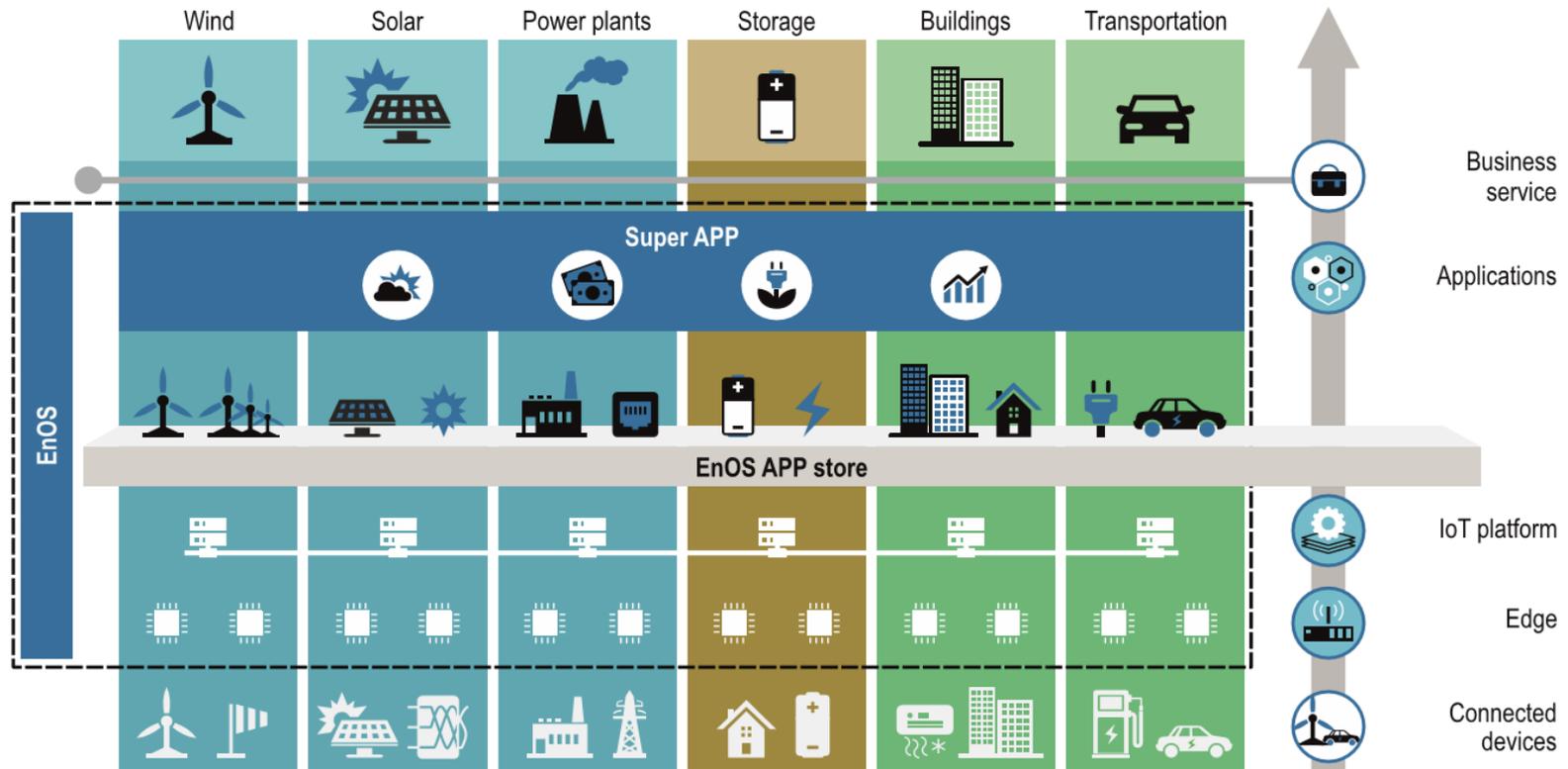
- A virtual power plant connects and aggregates distributed energy resources



Source: AGL

What the future could look like?

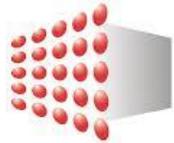
- A platform for Internet of things connects and manages a wide range of both generation and end-use technologies in order to enable collaboration at the level of households, communities and cities.



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 to SG \$ 100 million
- The aggregators become a game changer, and the future energy landscape requires an integrated policy, market design, and business models



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Thank you!

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