Integrating solar PVs and storage into long-term energy technology portfolio:

Business models innovation and lessons from Singapore

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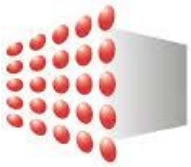

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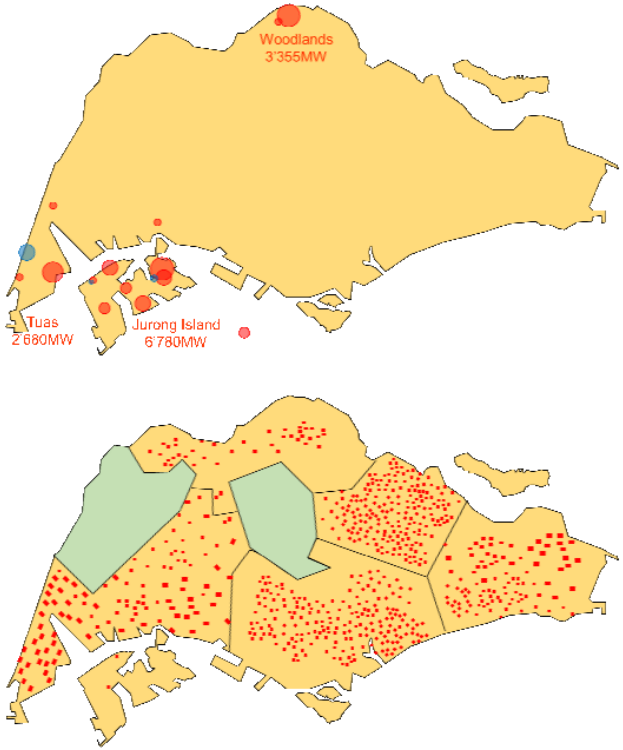
Singapore's energy transition

- Shift from highly centralized and natural gas-based system to a more distributed and sustainable energy system
- LCOE of Solar PV has reached grid parity in Singapore



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

Conventional on-demand power from centralised plant clusters

In 2017, 97% of electricity from a handful of CCGT/co-gen/tri-gen plants

Fossil fuel generating capacity (03/17)

Licensed:	13'348MW

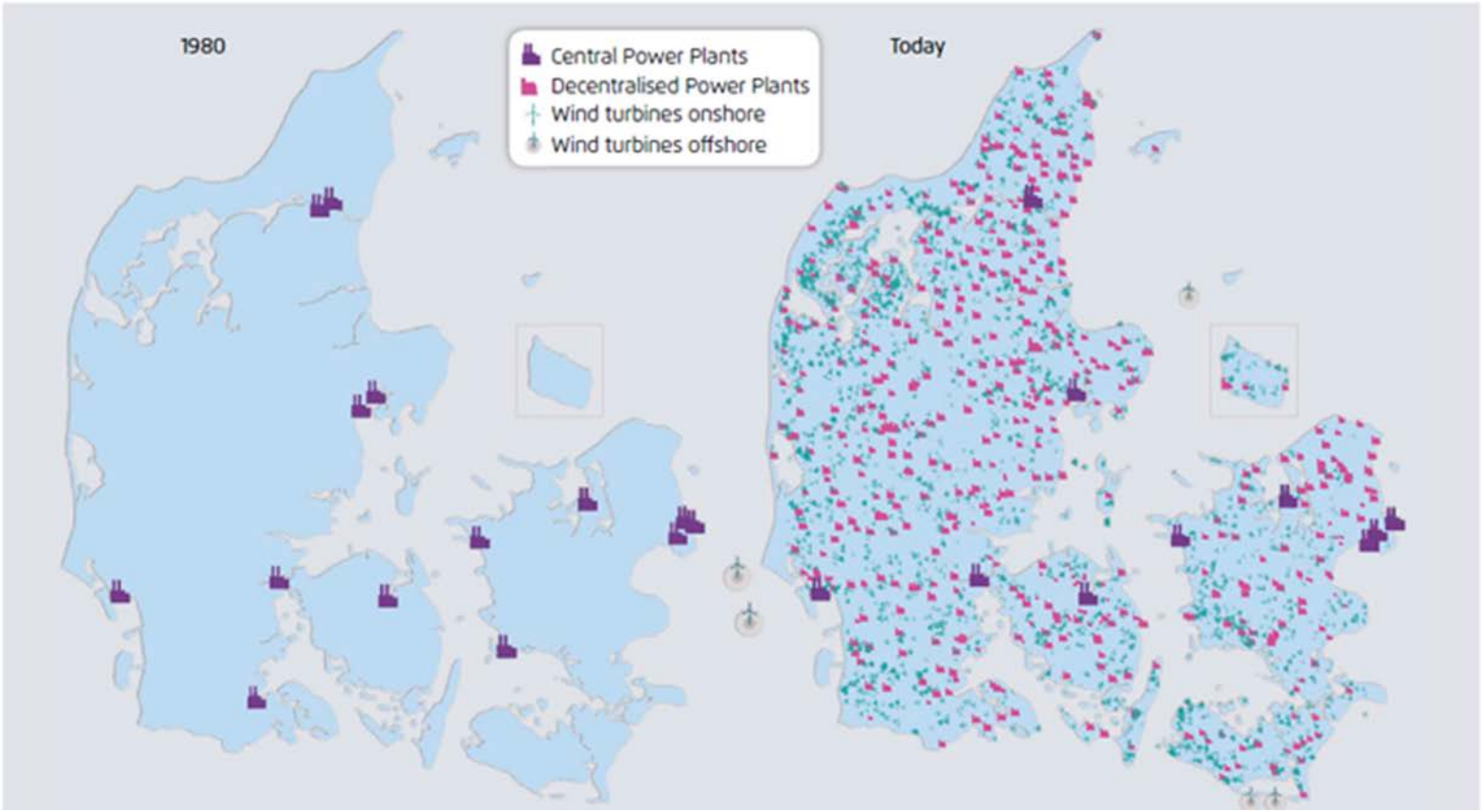
Weather-driven power from dispersed small-scale PV plants (~2'000 sites)

Installed PV:	136MWp
Backlog PV:	>100MWp
Central:	442
East:	379
NE:	491
North:	239
West:	405
Total sites (30/06/17):	1'956

Figure from Energetix

Nordic experience from central to distributed generation

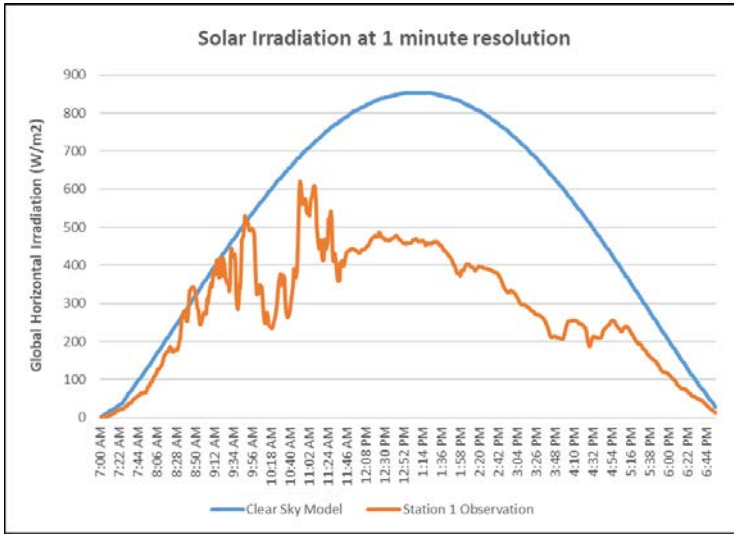
- Denmark's energy transition: CHP heat/power + decentralised solutions



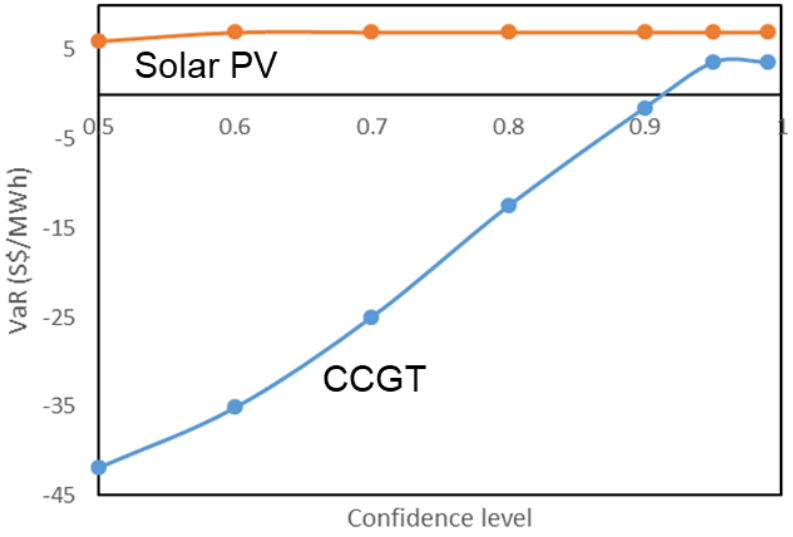
Source: Energinet

However, Singapore faces challenges

- Intermittency: the risk of a solar PV is higher than a CCGT



Source: Data from the National Environment Agency

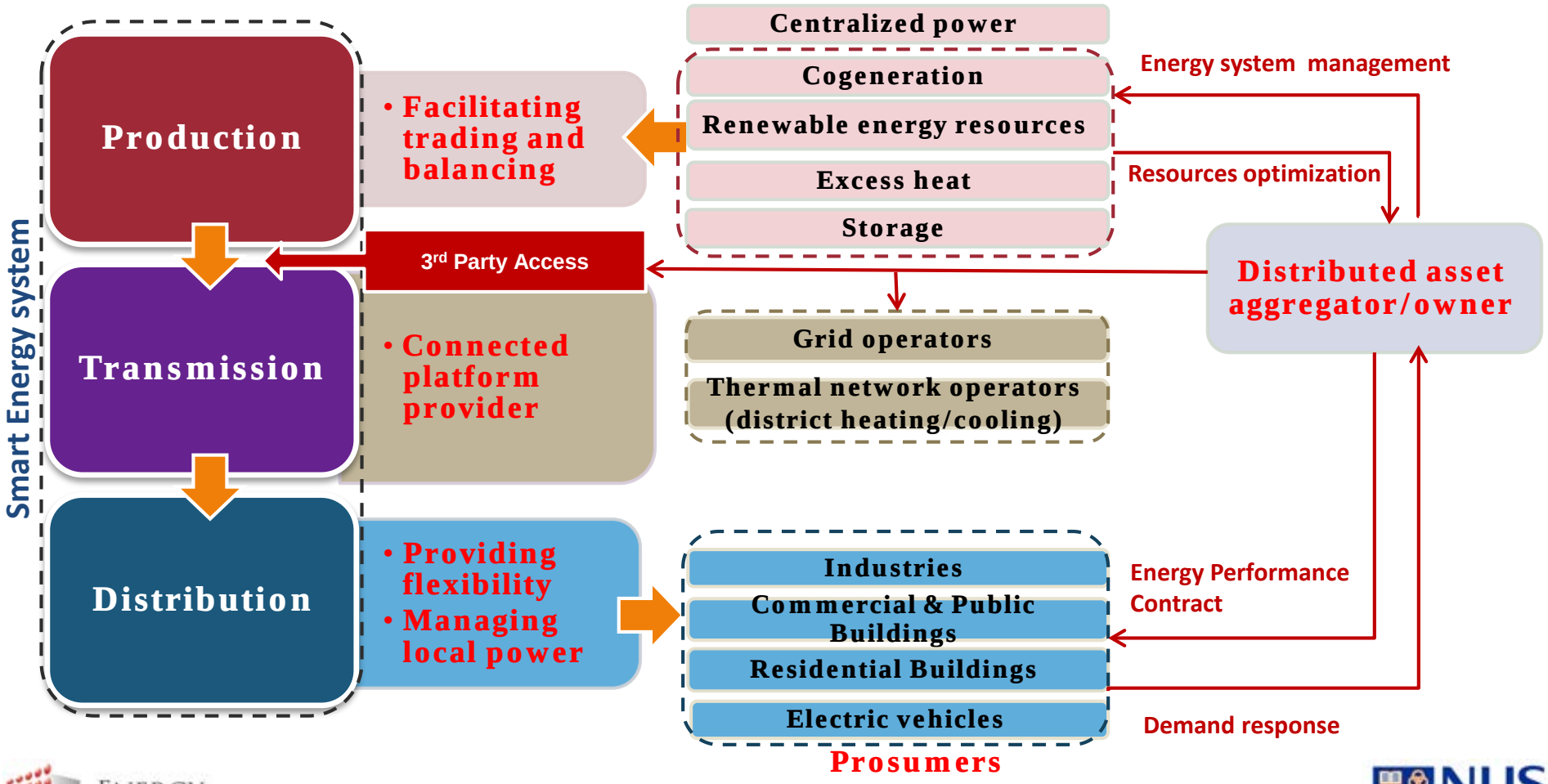


Source: Own study

- Land space : with technical maximum solar installation limit 10 GW, solar share can increase to 18.7% (on the basis of simulation results from our optimization electricity dispatch model).
  - Launched the world's largest floating solar photovoltaic (PV) test-bed worth USD 11 million in 2016

New market players and new roles

- Provide energy services beyond electricity as a commodity



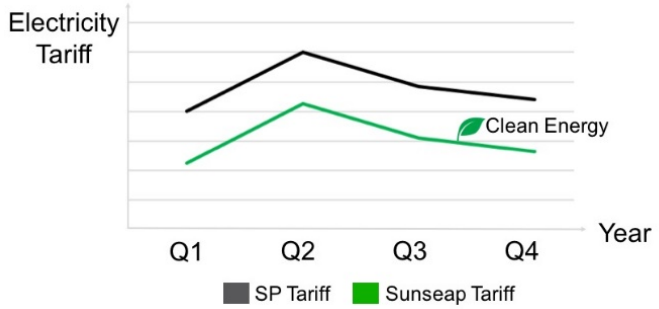
Source: own elaboration

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)

Rewarding storage in Singapore

- Key findings from our recent study:

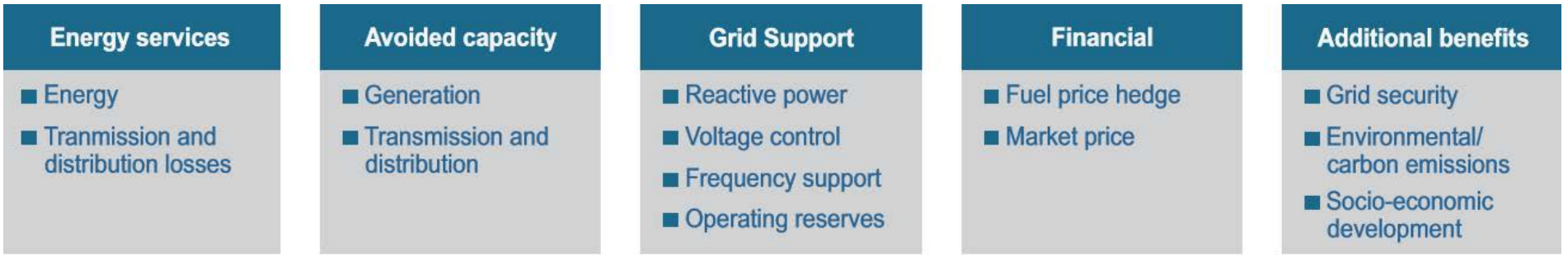
  - Arbitrage benefits from peak and off-peak electricity prices cannot make grid-level and behind-the-meter storage applications (storage alone and storage + solar PV) economically viable despite future storage cost reduction

  - The value of storage and DSM is only apparent when the renewable penetration is >10% in Singapore. The value is storage is 1% of the annual system costs.

Which solutions?

- The Intermittency Pricing Mechanism: internalise the frequency and magnitude of any output loss, and distribute the reserves costs.

- Rewarding storage and flexible loads requires a detailed analysis of the various value components.
  - Test-bed grid-level storage solutions with capacity of 4.4 MWh under Singapore's hot, humid and highly urbanised environment.



Source: IEA (2017)

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Thank you!

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