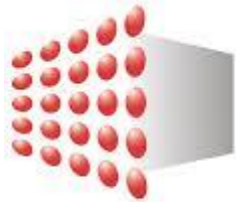


Singapore's Long Term Energy Future

Introduction



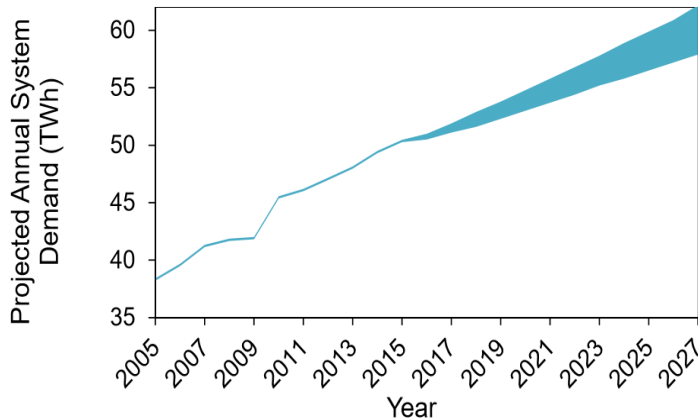
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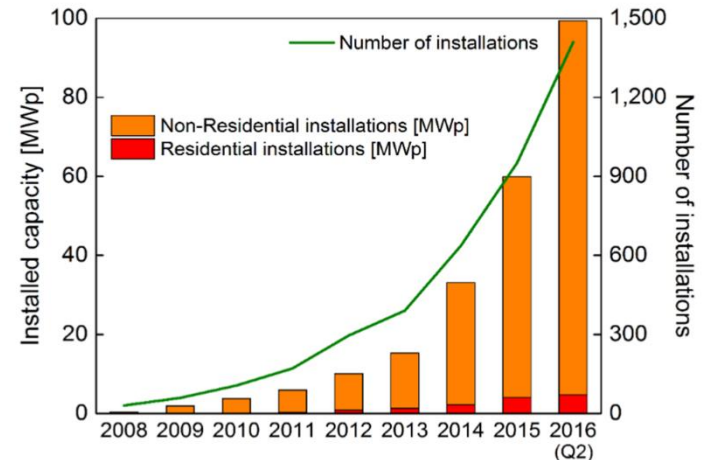
LIU Yang
Gautam Jindal

Singapore's Power System

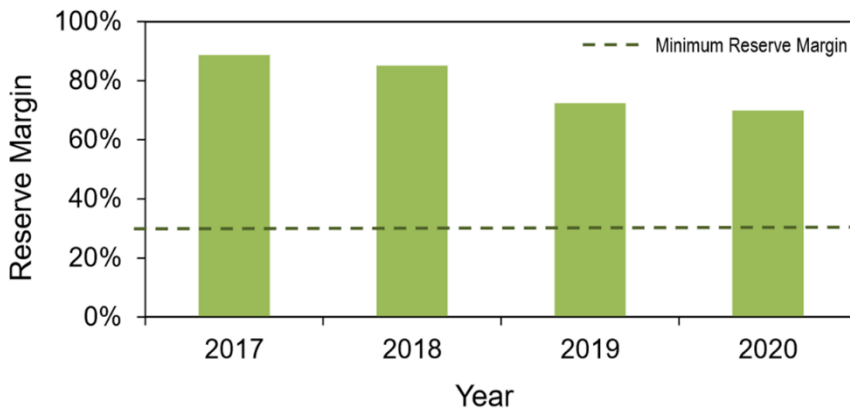
Singapore's projected electricity demand (2017-2027)



Growth in the number of solar installations and overall solar capacity ((2008 – 2016 Q2))



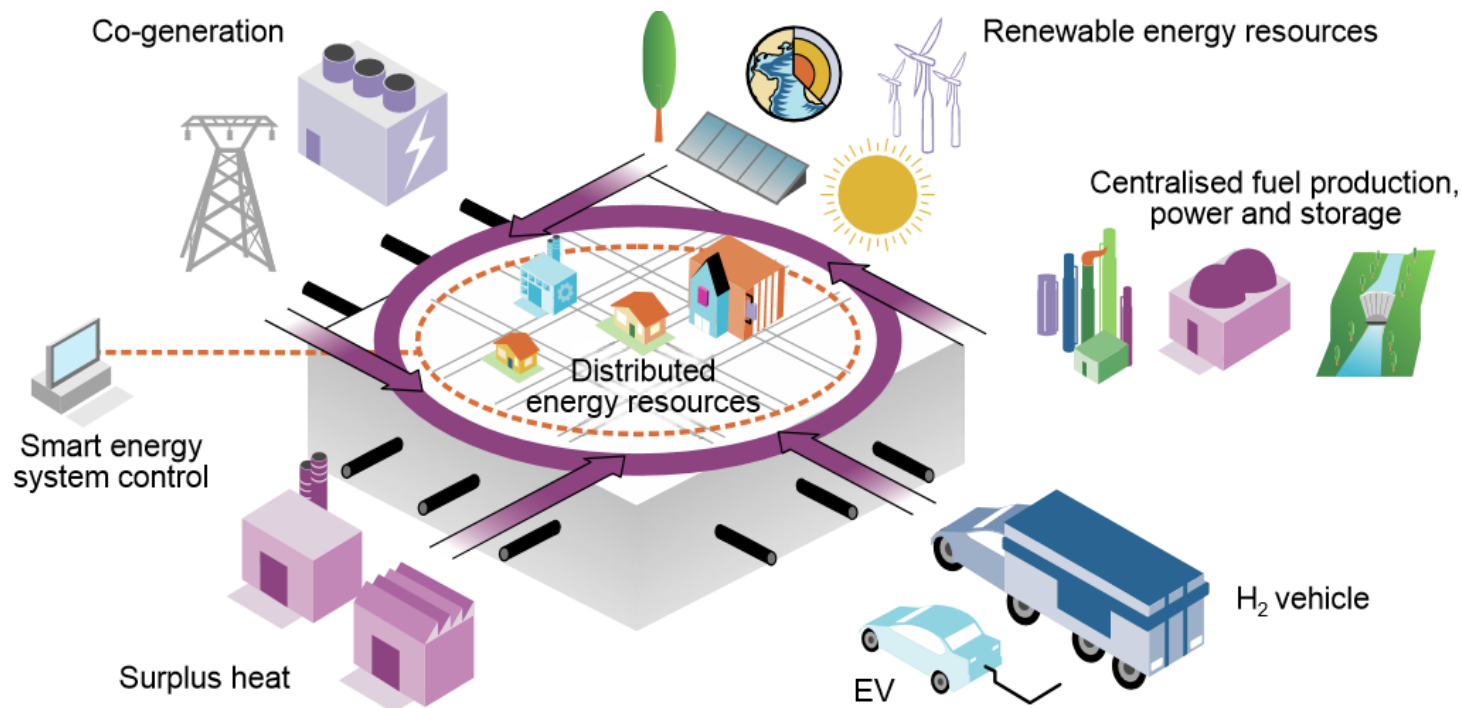
Reserve margin of electricity generation capacity



Source: EMA (2016)

System integration is essential for a sustainable energy future

- We need to move away from a one-directional energy delivery philosophy to a digitally-enhanced, multidirectional and integrated system.



Source: IEA (2017)

Integrated policy, market design and business models

Our research questions

- Can the current market mechanism in Singapore **reflect the values** (current and projected) of solar PVs, storage and VPPs?
- How to **quantify the values of improved flexibility** brought by the integration of solar PVs, storage and VPPs?
- How would the participation of storage and VPP in the electricity market change **business models** in the market?
- What **policy framework** is needed to support the viability of different business models?

Singapore's Climate Pledge

Singapore ... intends to

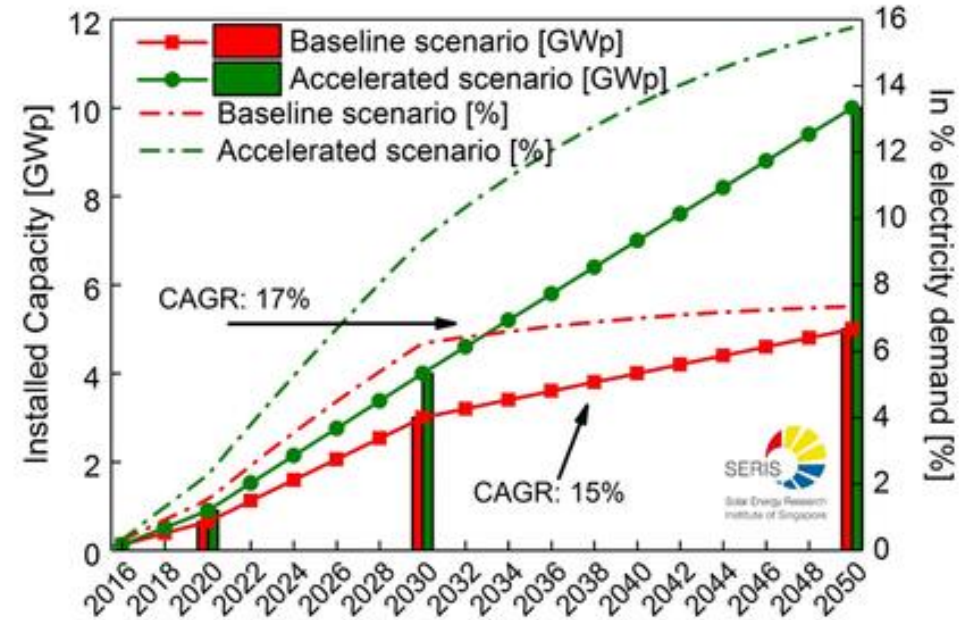
reduce its (GHG) Emissions Intensity by 36% from
2005 levels by 2030,
and stabilize its emissions with the aim of peaking
around 2030.

Limited Reduction Options

- Carbon efficient power generation (> 95% CCGT, > 2% WTE)
- Limited potential for wind, hydro, biomass, Nuclear??
- High share of public transport
- 31% building stock Green Mark; target 80% by 2030
- Main Reduction Options
 - Industrial Energy Efficiency
 - Solar PV

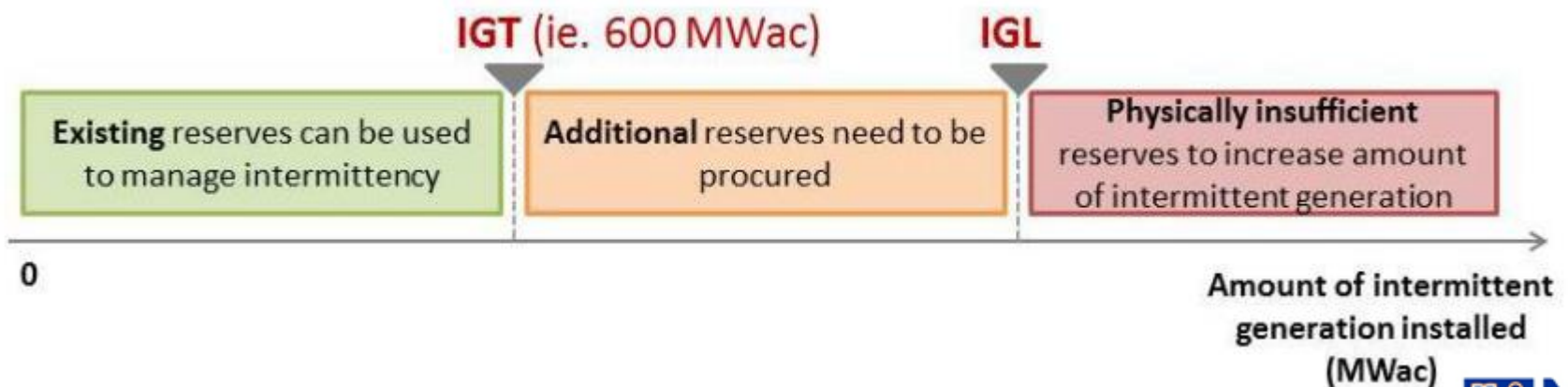
Solar PV in Singapore

- Current installed PV 140 MW
- 350 MW by 2020
- 1 GW beyond 2020
 - Driven by public housing estates, industrial rooftops
- Long Term PV outlook 13 – 14 GW by 2050
 - > 50% rooftop, Rest on islets, floating, facades
- No FiT for PV; sells at discount v/s regulated tariff



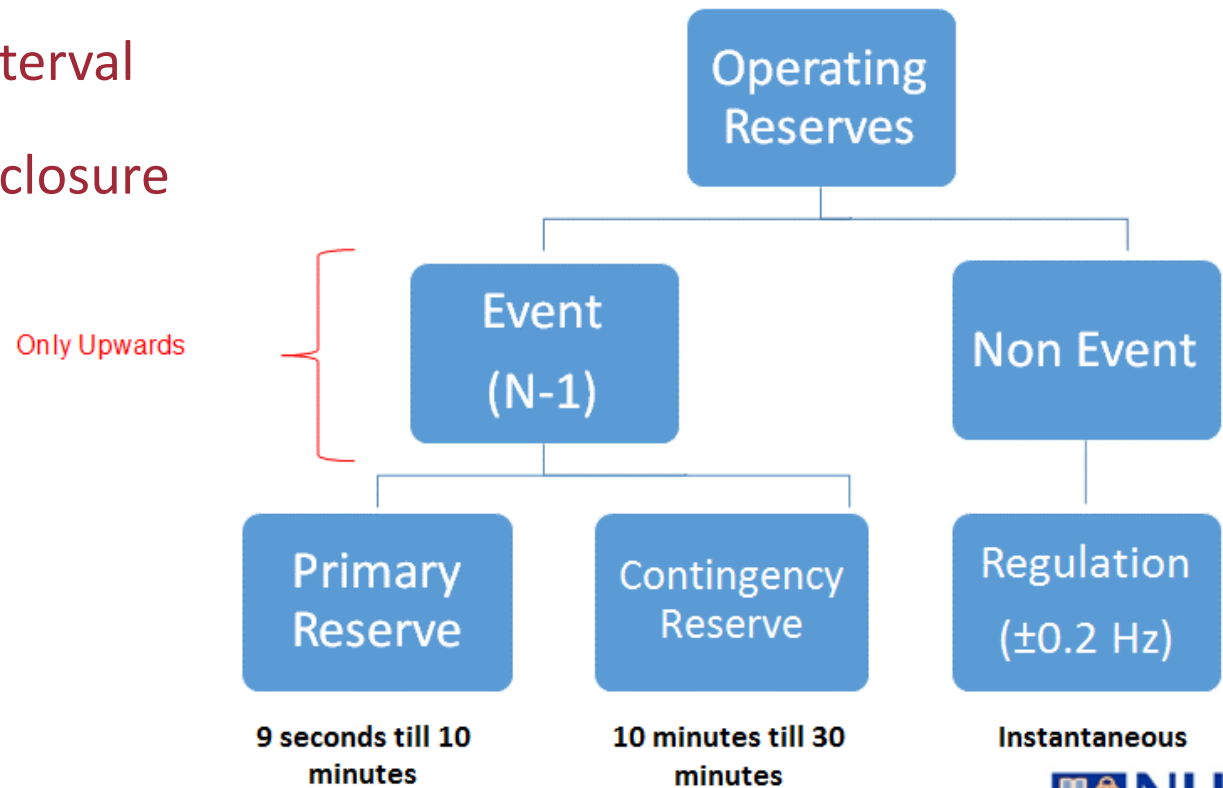
Solar PV in Singapore

- Intermittency concerns
 - System Average Interruption Duration Index (2016) 0.25 min
- PV classified as “Intermittent Generation Source” (IGS)
 - Pre – 2014: Hard cap of 350 MW
 - Dynamic Pathway Approach



Singapore's Electricity Market

- Liberalized electricity market
 - Co-optimized Energy and Frequency Control Services
 - 30 min dispatch interval
 - 65 min (soft) gate closure



Recent Updates

- ESS allowed to participate in Regulation market
 - No Performance Incentive
 - Average Regulation Price S\$/MWh 8 (2016), 18 (2015)
- Regulatory Framework for ESS under stakeholder consultation
- “Intermittency Pricing Mechanism” under consultation
 - Aggregate PV systems to account for geographic smoothing
 - Frequency & Magnitude of deviations

Key Challenges

- IGS grid integration: installed PV capacity – 0.6 GW -> 14 GW
 - Variability & Uncertainty
 - Impact on “Regulation” & “Reserve” Requirements??
 - Optimizing market design
- Business case & Framework for Storage
- Role of Virtual Power Plants