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The challenges of the energy transition in the context of the Singapore Wholesale Electricity Market (SWEM)

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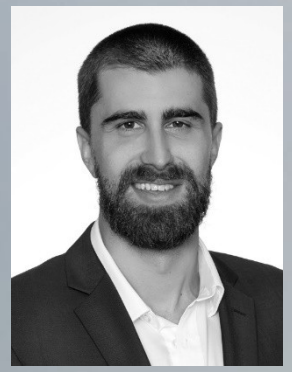
Agenda

1. Introduction
2. Setting the scene
3. Emissions reduction targets & policy
4. Renewable imports
5. Transitioning to hydrogen blend fuels
6. What else is being considered?
7. Q&A

Who am I?

- Senior manager in EY's electricity market modelling team (EY-ROAM)
- Started with EY in 2016
- QUT graduate in electrical engineering (2016)
- Chartered engineer with EA
- Brief stints in building services engineering and working in distribution
- Commercial electrician



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EY- ROAM electricity market modelling

EY-ROAM is a leading provider of electricity market modelling services in Australia. Our modelling suite has been developed in-house for over 20 years, since the start of the National Electricity Market in Australia (NEM).

Our team comprises of experienced market analysts, power system engineers and software engineers.

We have experience modelling multiple markets including the NEM (east coast Australia), WEM (Western Australia), NZEM (New Zealand) and SWEM (Singapore).

NEM | WEM | NZEM | SWEM

Our offerings include:

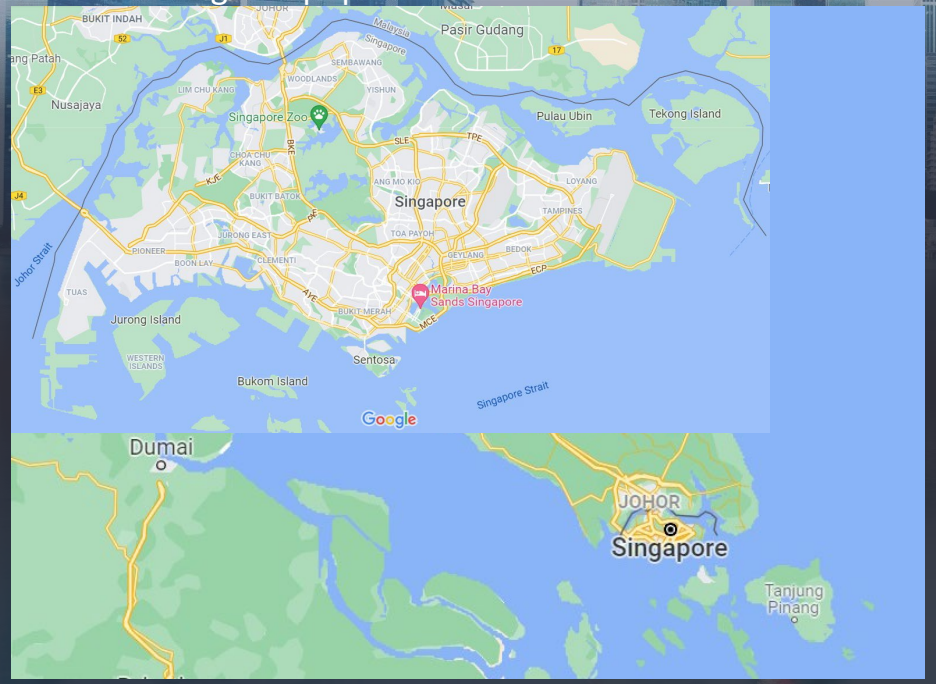
- Scenario-based market outlook studies
  - Wholesale electricity price forecasting
  - Loss factor modelling (MLF and DLF)
  - Network curtailment studies
  - Emissions forecasting for the electricity sector
- FCAS price forecasting
- Long-term whole of system planning studies
- Generation and transmission development planning
- Energy policy development
- Market design research and review

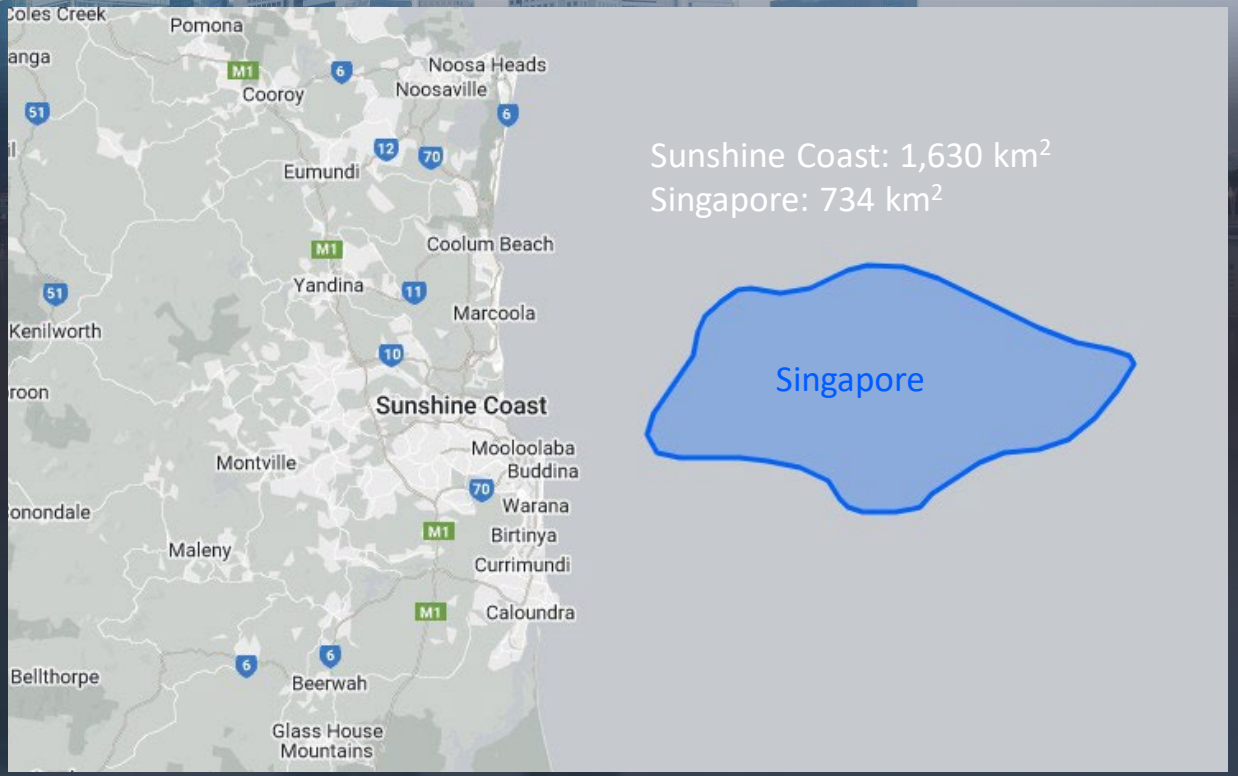
Clients:

- Renewable developers and asset owners
- Lenders and investors
- State and federal Governments
- Transmission and distribution network service providers
- Market operators and governing bodies

Setting the scene: Geography

Where: Tiny island off the southern tip of Malaysia
Population: 5.6 million
One of the highest population densities in the world



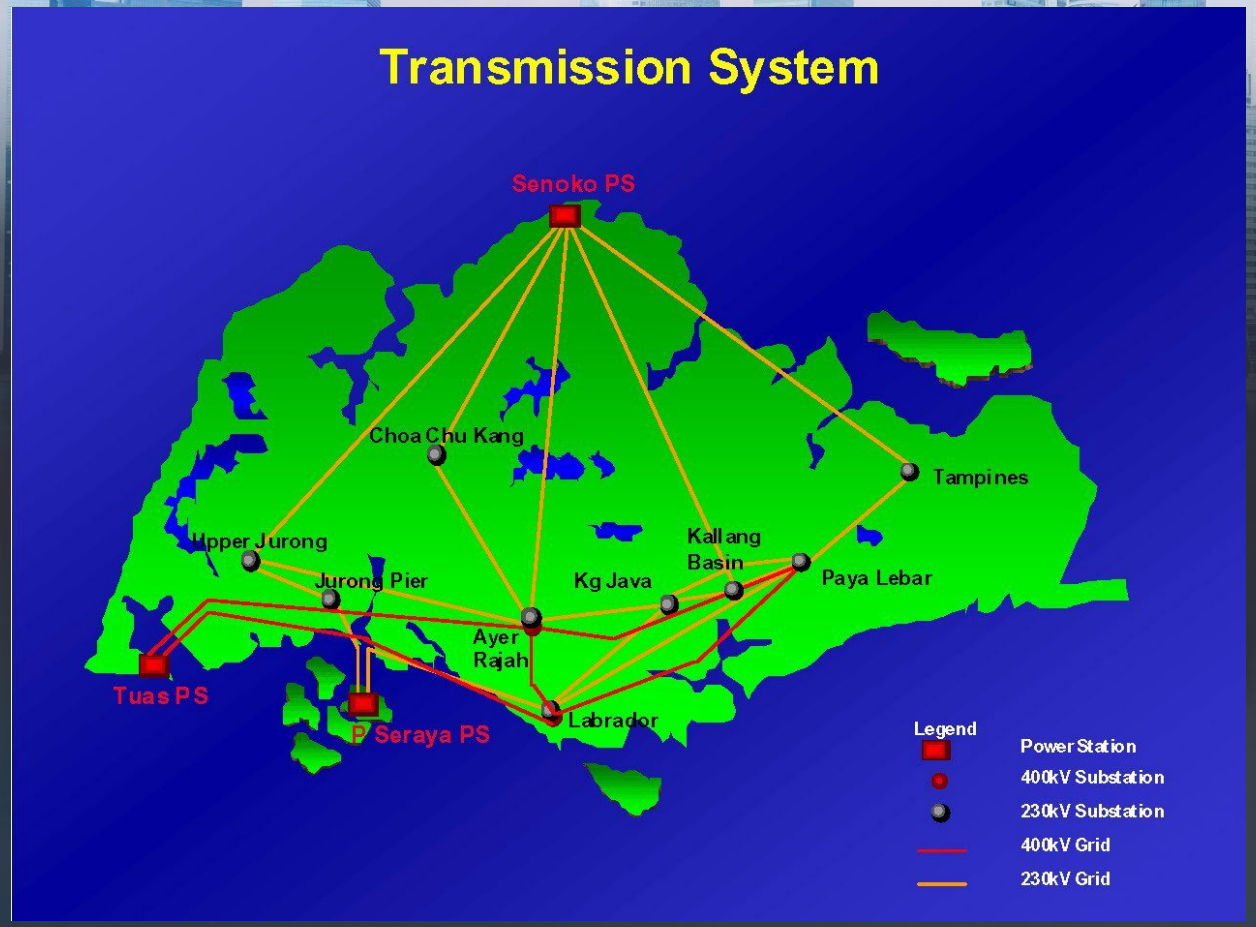


Sunshine Coast: 1,630 km^2
Singapore: 734 km^2

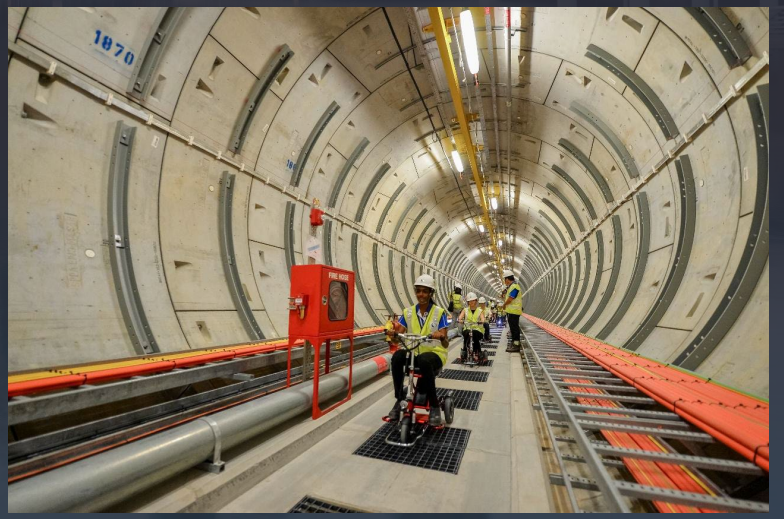
Tropical climate:

- 23-32^{o}C with a high chance of rain
- Rains ~170 days per year
- Monsoons from Nov-Feb

Setting the scene: Network

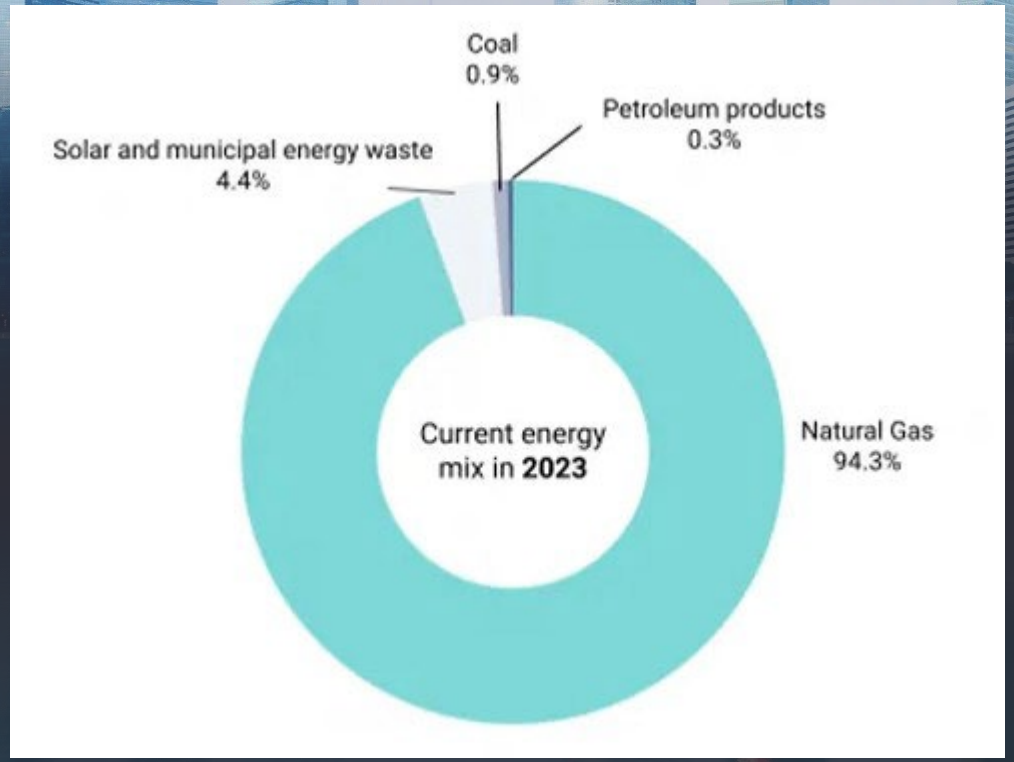


- All underground
- Cable tunnels as deep as 60m
- Currently no issues with network congestion
- Interconnection with Malaysia. Mainly used in system security events and import trials.
- Plans for renewable imports via subsea HVDC



Source: SP Group, 2024

Setting the scene: Energy mix



Source: EMA, 2024

- In 2023 94.3% of generation came from natural gas, mostly CCGTs
- Some existing solar (~770 MWac) and waste-to-energy plants
- Solar is an option but is geographically constrained
- Wind is not a great option: average wind speeds of 2-3 m/s. Most commercial wind turbines operate at avg wind speeds of at least 4.5 m/s
- Offshore wind challenging due to busy marine traffic

Setting the scene: Solar

Tengeh Floating Solar Farm (60 MWp) on the Tengeh Reservoir

Figure 5: Solar Irradiation at a Single Location: A clear sky in the early morning, followed by a cloudy midday and an afternoon storm. The intermittency is obvious

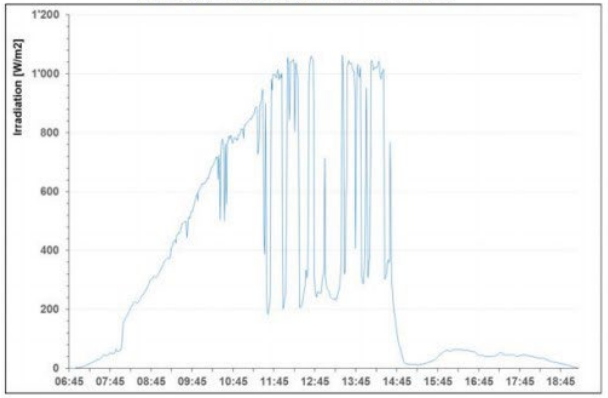
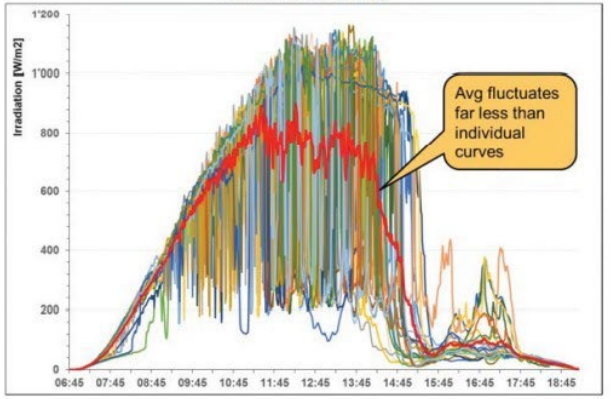


Figure 6: Averaged over 25 Sites across Singapore: The solar irradiation varies rather smoothly

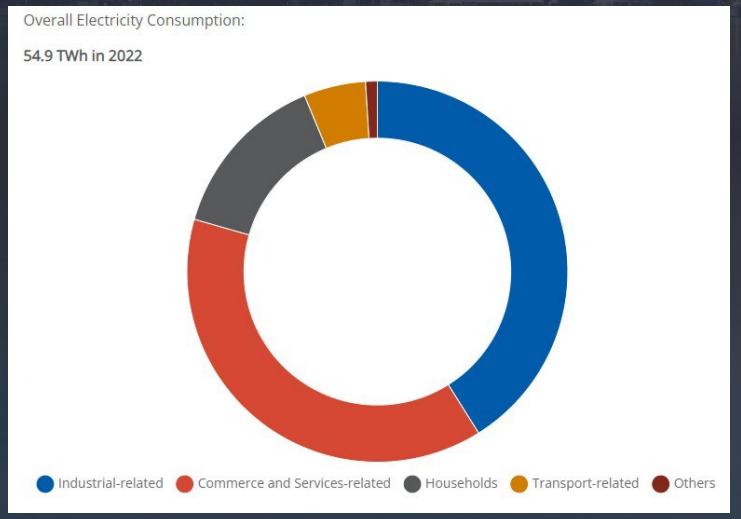


Source: Image generated from data courtesy of the Solar Energy Research Institute of Singapore (SERIS).

- Frequent cloud cover means low capacity factors and variability for solar (~16-17% vs ~20-30% in Australia)
- Maximise deployment of solar panels on available surfaces:
  - Rooftops
  - Reservoirs
  - Exploring offshore sea space and vertical surfaces of buildings

Setting the scene: Demand

- ~60 TWh annual energy consumption
- ~8 GW peak demand
- Demand profile is currently very flat
- Demand is expected to grow due to growth in electricity-intensive sectors such as data centres and transport (through electrification of vehicles).



Source: EMA 2024

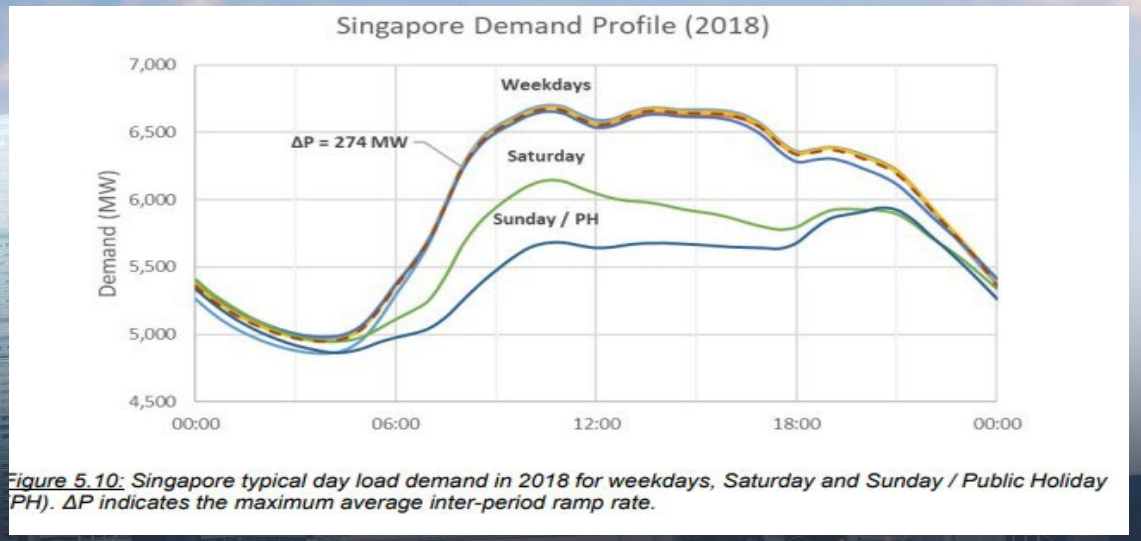
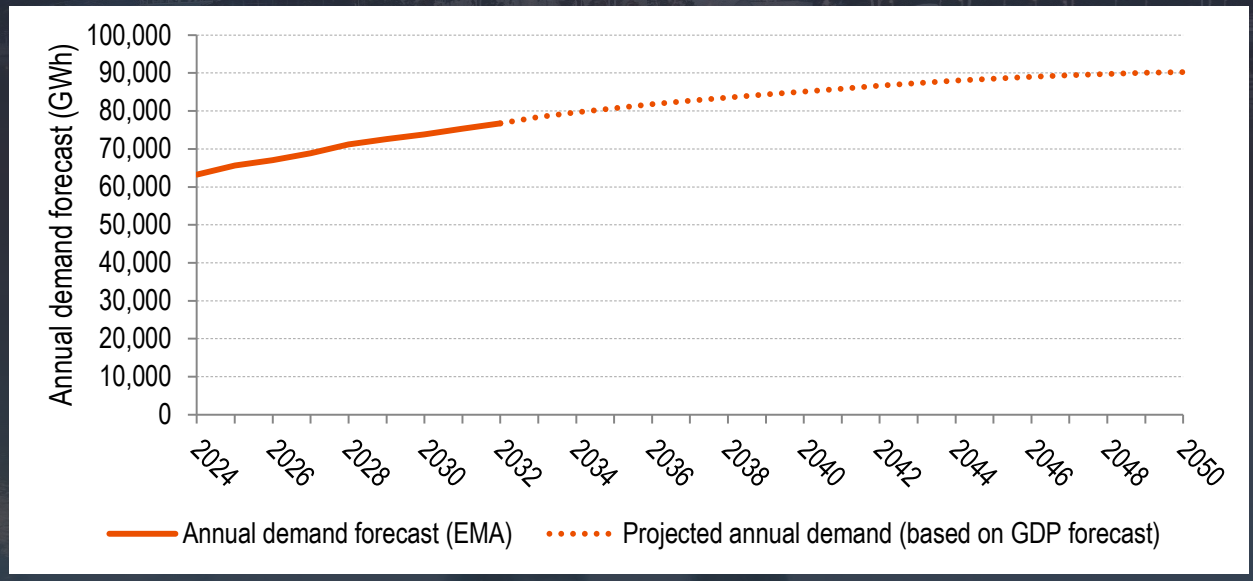


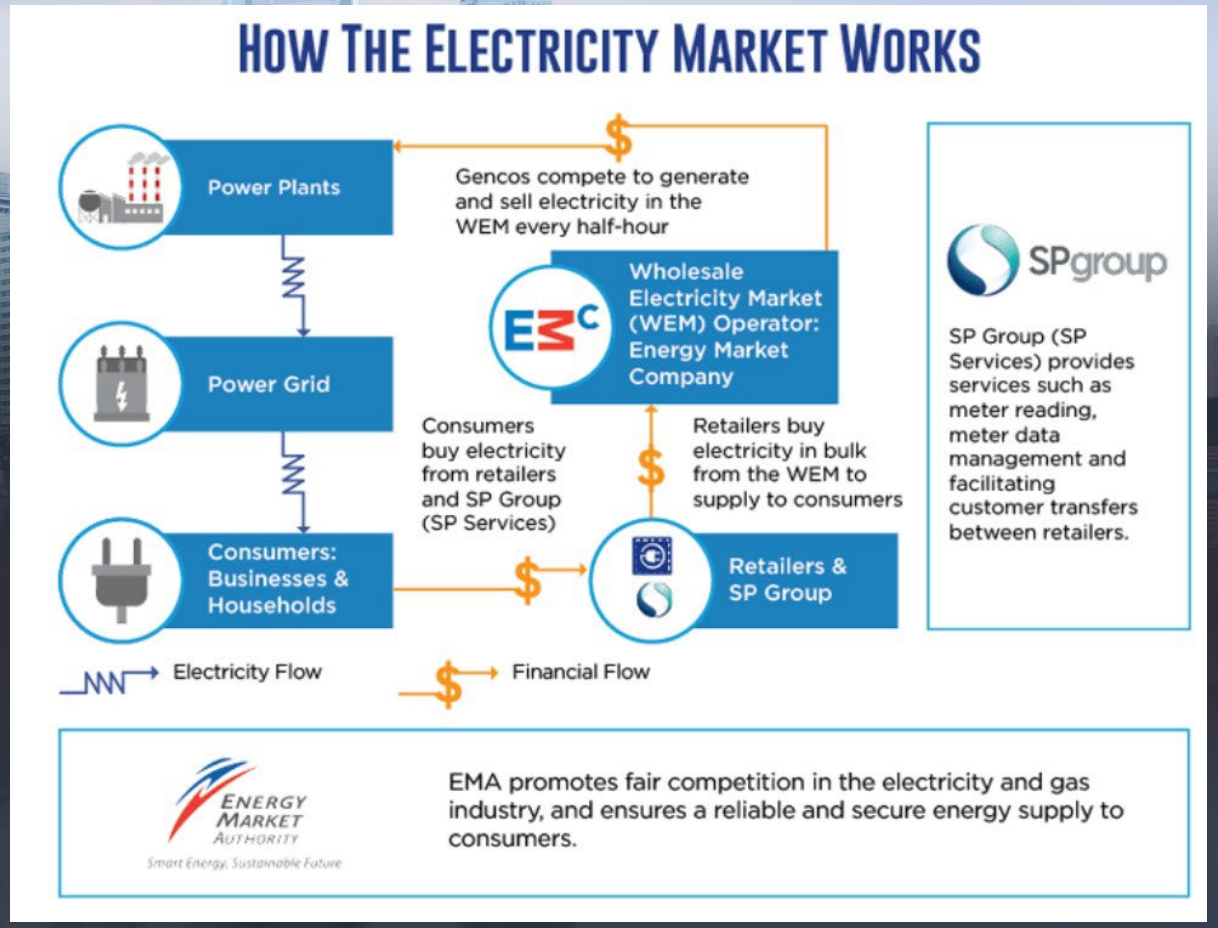
Figure 5.10: Singapore typical day load demand in 2018 for weekdays, Saturday and Sunday / Public Holiday (PH). ΔP indicates the maximum average inter-period ramp rate.



Source: EMA 2024

Setting the scene: Market design

- Gross pool energy only market.
- Least cost dispatch by EMC's market clearing engine.
- Nodal market (113 injection nodes and 873 withdrawal nodes).
- Uniform Singapore Energy Price (USEP): Weighted average of the nodal prices at offtake nodes. Generators receive nodal price and consumers pay USEP.
- 27% Reserve margin:
  (Installed capacity – peak demand)/peak demand
- Reserve and regulation real time market.
- Procurement market for other ancillary services.



Source: EMA 2024

Emissions reduction targets & policy

In late 2022, Singapore committed to achieve net zero emissions by 2050 as part of their Long-Term Low-Emissions Development Strategy. About 40 per cent of Singapore's greenhouse gas emissions now come from the power sector.

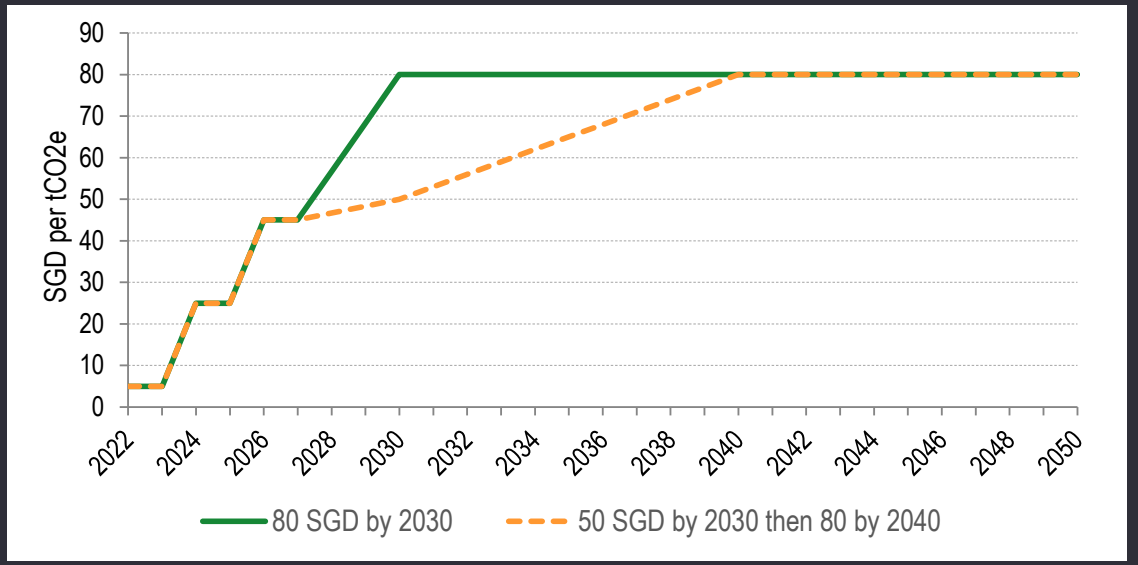
Current policy and targets:

- $5 per tonne carbon price introduced in 2019.
- The carbon price will increase to $25 in 2024-2025, then $45 in 2026 and 2027 before reaching $50 to $80 per tonne by 2030.
- Solar target of 1.5 GWp by 2025 and 2 GWp by 2030
- Storage target of 200 MW by 2025.
- 4.2 GW renewable imports (following slides)
- New emission standards for power generation units (following slides).

Centralised processes:

- Central capacity procurement process by EMA (regulator). No free entry/exit.
- Plans for central gas procurement.

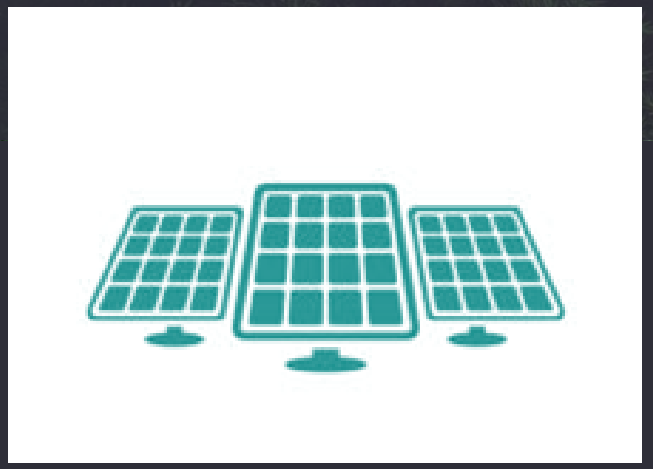
Carbon price outlook



Renewable imports

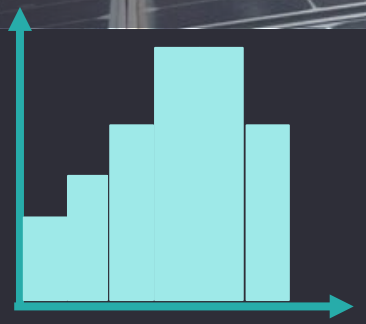
2 GW of solar from Indonesia by 2028 (firmed by 2033)
2.2 GW of imports from Vietnam and Cambodia by 2035 (firmed by 2040)

75% load factor



Emissions factor ≤ 0.15 tCO2/MWh within 5 years

No coal/nuclear



HH firmed generation

Imports begin intermittent at first, then 75% load factor firmed quarterly required 5 years from commissioning

Renewable imports

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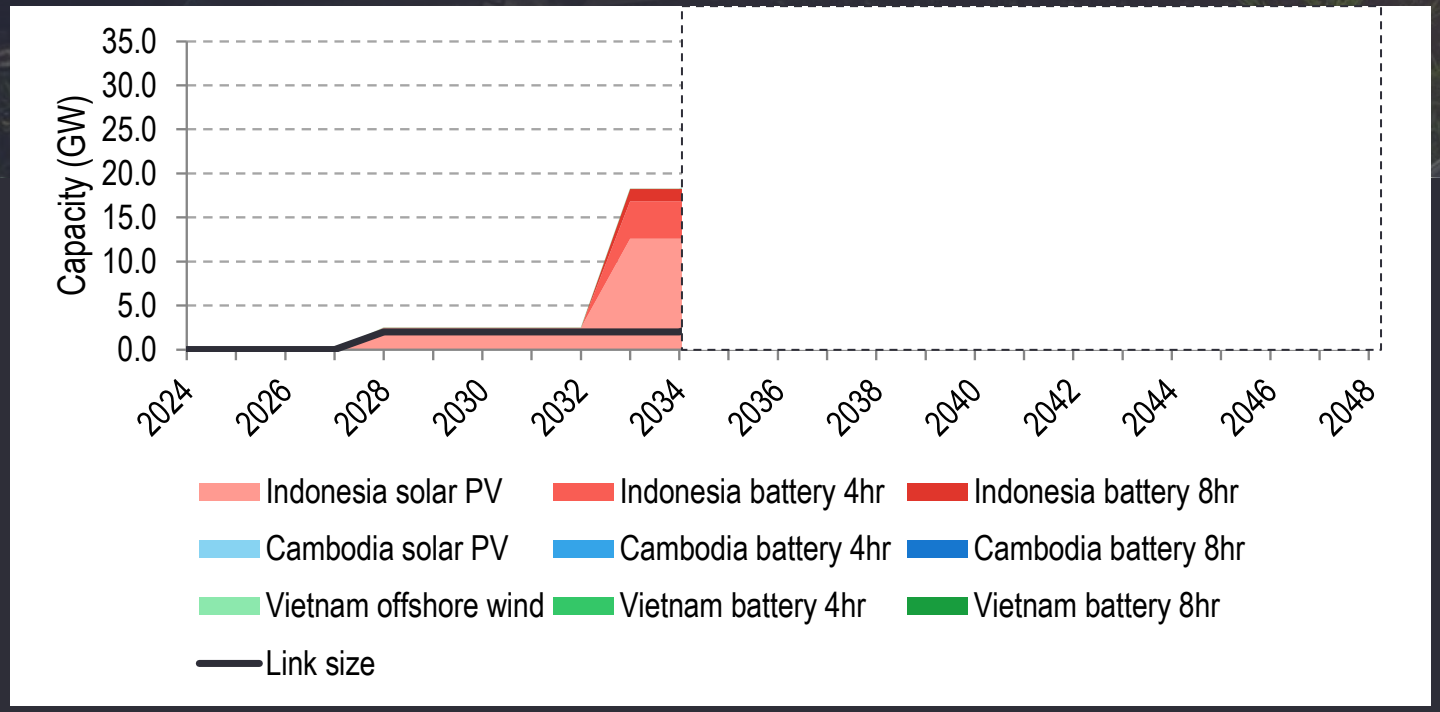
2.2 GW of imports from Vietnam and Cambodia by 2035 (firmed by 2040)



Source: EY modelling

- Using EY's resource planning model which forecasts least-cost dispatch and generation mix

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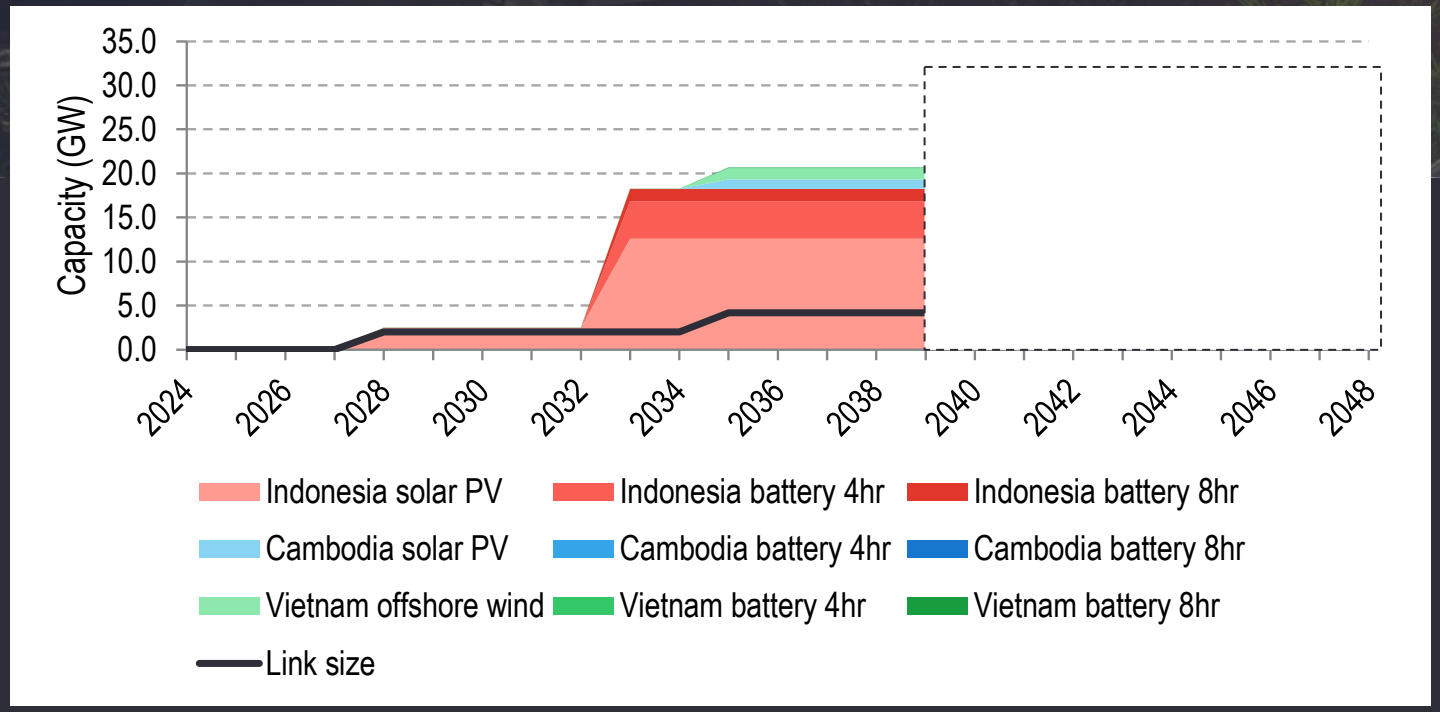

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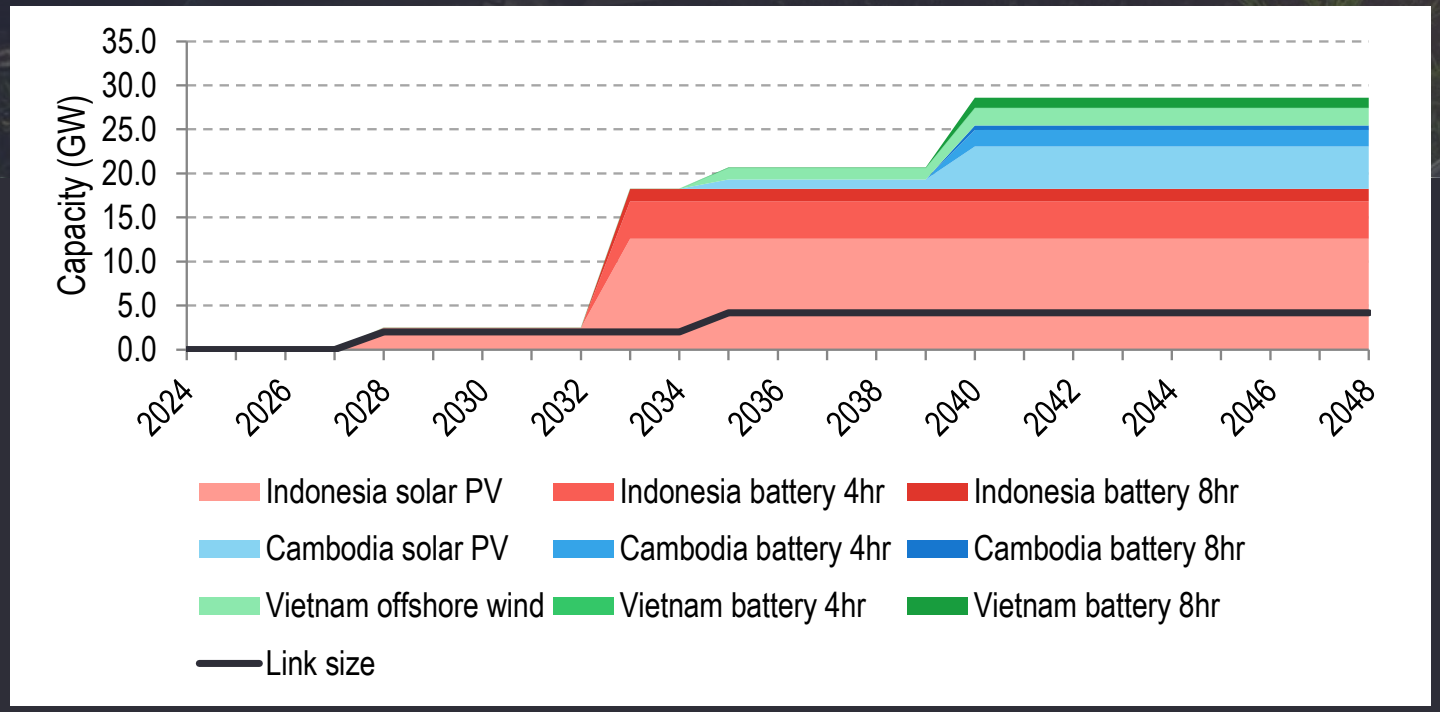


Source: EY modelling

- Using EY's resource planning model which forecasts least-cost dispatch and generation mix

Imports begin intermittent at first, then 75% load factor firmed quarterly required 5 years from commissioning

Transitioning to hydrogen blend fuels

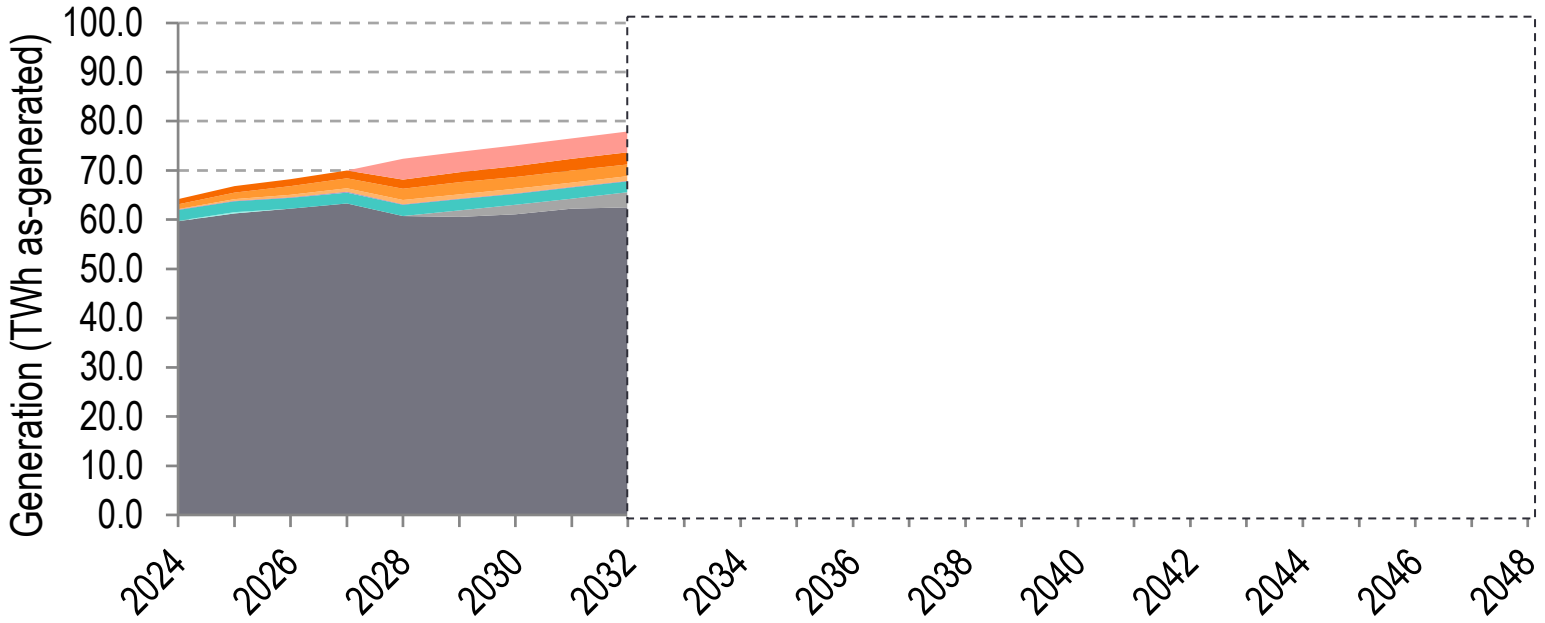
EMA’s new emissions standard

- Emissions intensity limit and annual emissions cap for new gas generators.
- All newly constructed OCGTs and CCGTs from 2024 need to be at least 30% hydrogen-ready by volume, with the ability to be retrofitted to 100% hydrogen in future.

Economics don’t stack up

- Under current hydrogen price forecasts units running on hydrogen blends are not going to be cost competitive with traditional gas for quite some time.
- There would need to be a mandate in place to enforce running on these fuels. Or a subsidy.

Under the current plans what could the future look like?

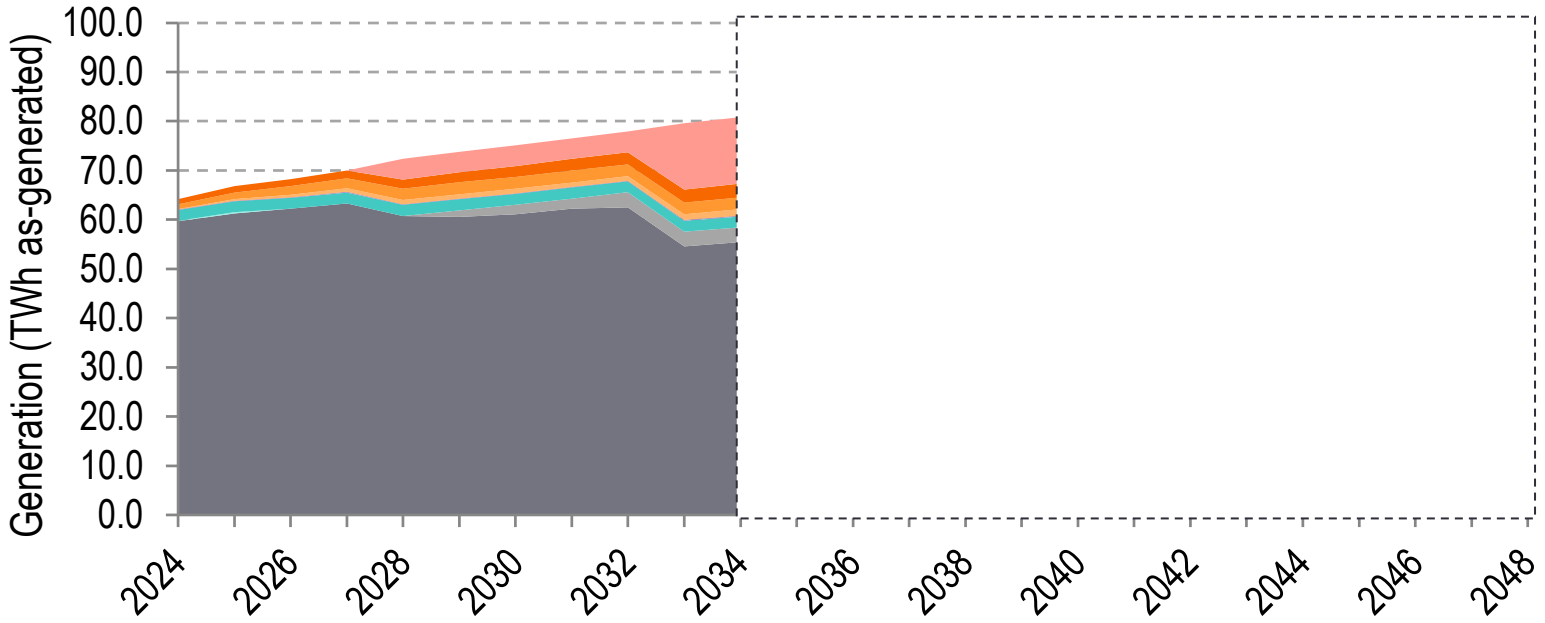


- Local renewable targets met
- First stage of import capacity by 2028 (unfirmed)
- Carbon price reaching $80/tonne
- Some gas retirements

- Using EY's resource planning model which forecasts least-cost dispatch and generation mix.

Source: EY modelling

Under the current plans what could the future look like?

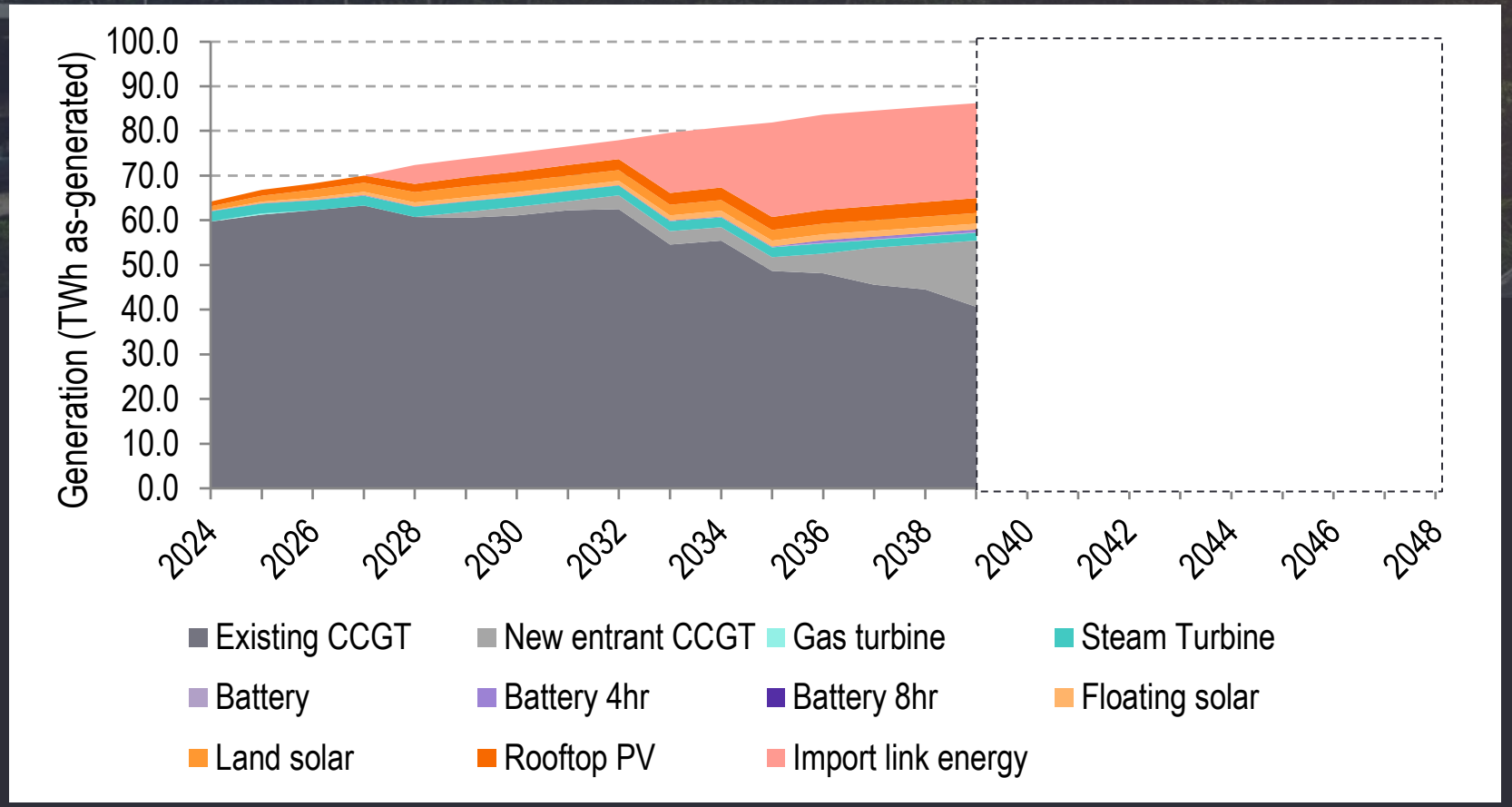


- First stage of import capacity firmed to 75% by 2033
- Further gas retirements
- New gas running on 30% hydrogen blend fuel under assumed 2030 mandate

- Using EY's resource planning model which forecasts least-cost dispatch and generation mix.

Source: EY modelling

Under the current plans what could the future look like?

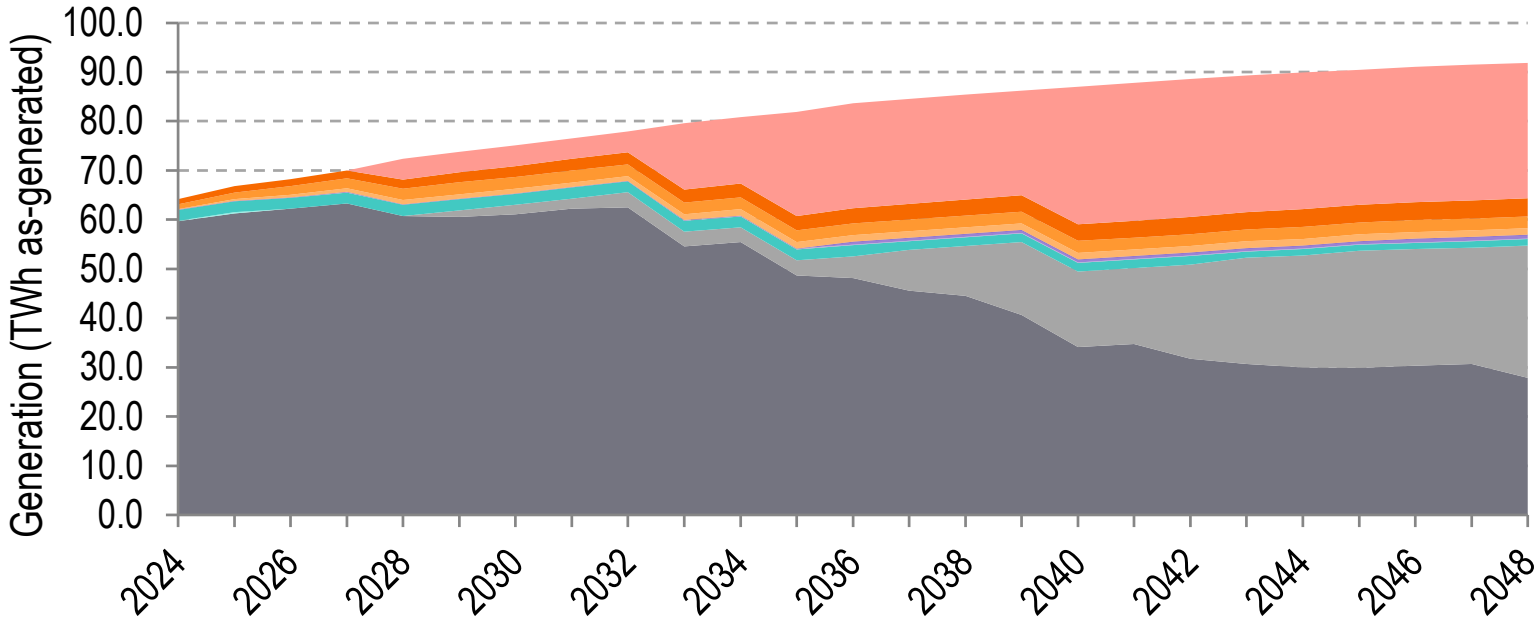


- Second stage of renewable imports in 2035.
- Further gas retirements.

- Using EY's resource planning model which forecasts least-cost dispatch and generation mix.

Source: EY modelling

Under the current plans what could the future look like?

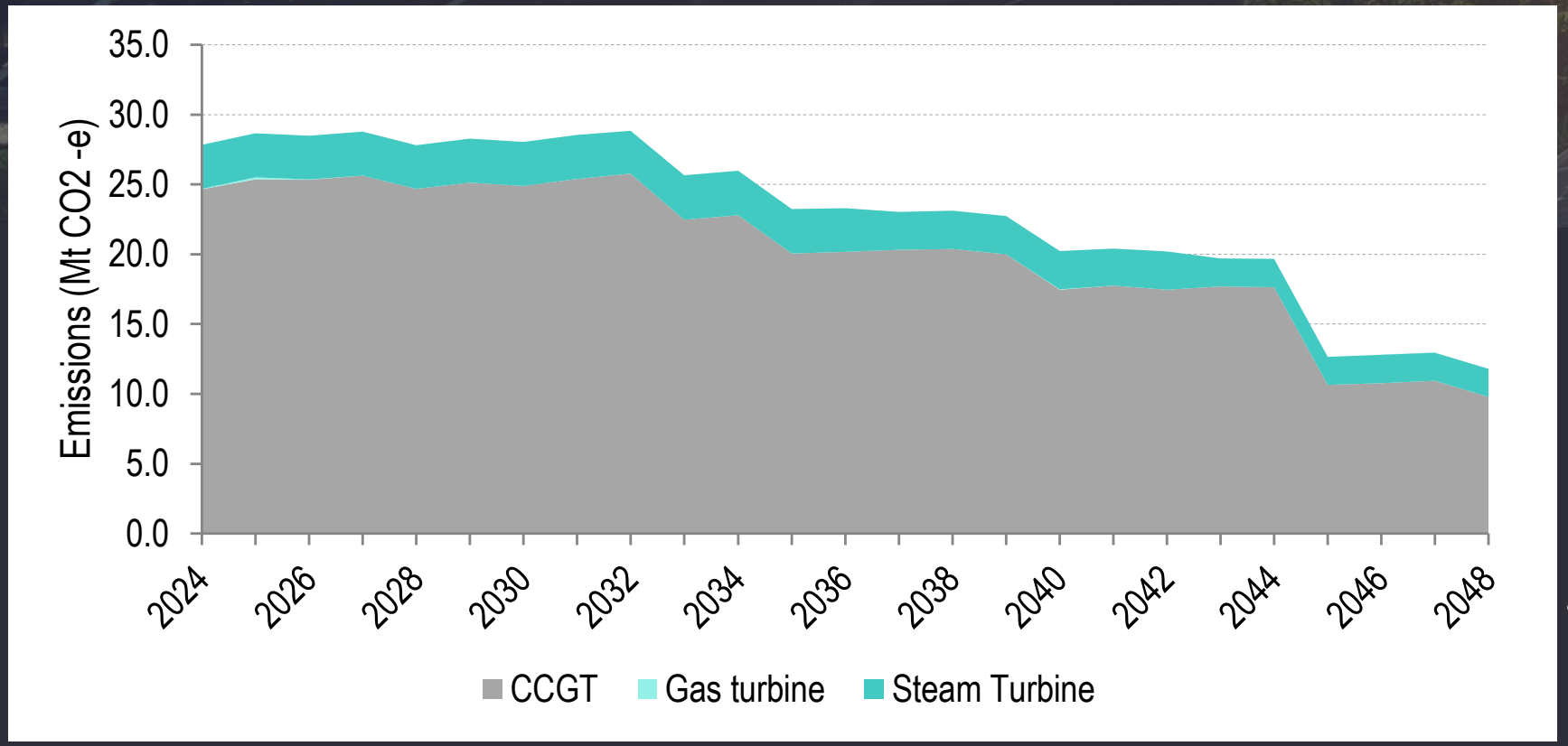


- Second stage of renewable imports firmed to 75% by 2040
- New gas from 2045 running on 100% hydrogen blend fuels under assumed mandate.

- Using EY's resource planning model which forecasts least-cost dispatch and generation mix.

Source: EY modelling

Under the current plans what could the future look like?



- Even under current ambitious plans there's still going to be electricity sector emissions remaining by 2050.
- Would require offsets in other parts of the economy.

- Using EY's resource planning model which forecasts least-cost dispatch and generation mix.

Source: EY modelling

What challenges/risks do the current plans present?

Local renewable targets

- Solar is one of the only renewable options but geographically constrained, low energy yield and high variability.
- BESS profitability is low in short-term due to flat TOD prices. Limited arbitrage opportunity.

Renewable imports

- Costly (revenue support required)
- Energy security and reliability?
  - Sustained subsea cable outages
  - 3% failure rate
  - 3.5 months mean time to repair
- Project delays
- Geopolitical risks
- System strength & inertia shortfall
- Future congestion risk at injection points?

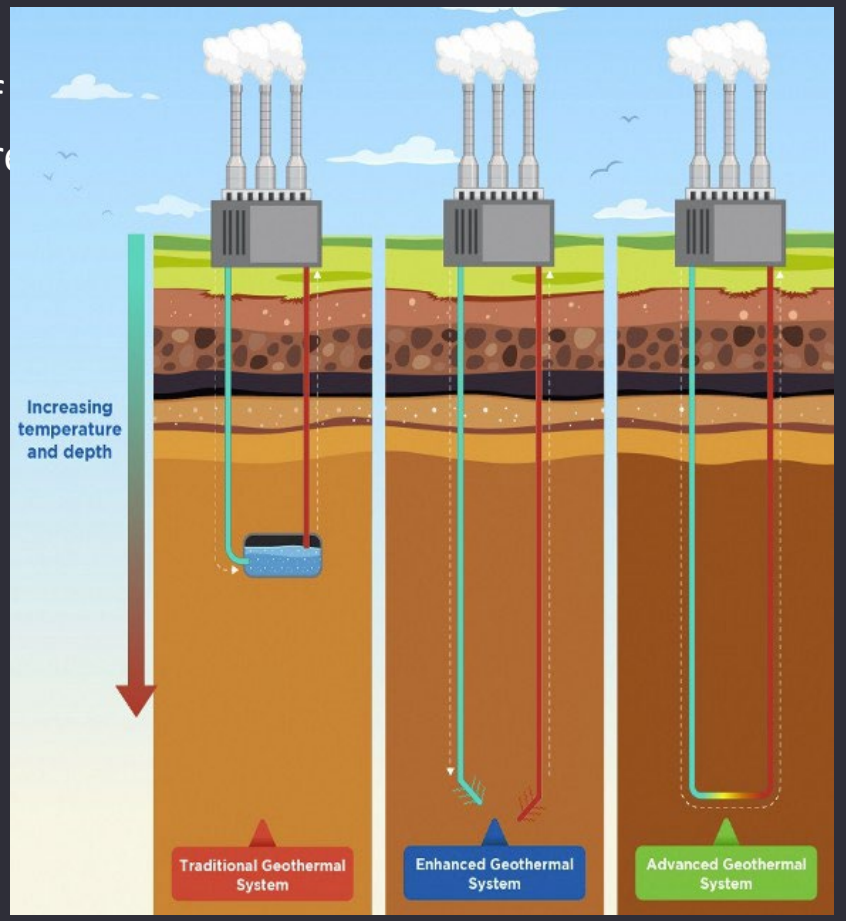
Hydrogen blend fuels

- New technology largely unproven at scale
- Hydrogen is going to be expensive as a fuel for quite some time.
- Economics not there so mandate or subsidy would be required.

-

What else is being considered?

- Geothermal:
  - Recently, advances in drilling technology have unlocked the potential of geothermal energy as a potential renewable energy source for Singapore 2-year study starting later this year.
- More renewable imports above the 4.2 GW
- Nuclear?



Source: EMA, 2024

Thank you

We’re hiring!

- Senior consultants/managers
- Senior software and data model developers
- 2025 graduates

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EY modelling framework

The EY electricity market modelling team has developed modelling capabilities for the National Electricity Market of Singapore using it's two in-house optimisation models, 2-4-C and Time Sequential Integrated Resource Planner (TSIRP). Both models are used together to determine possible market outlooks under different scenarios.

TSIRP

TSIRP is a long-term planning tool which solves for least cost expansion pathways for generation capacity, the network, energy storage and demand response. In the Singapore market context, this model can be used to determine the optimal capacity and technology mix to meet the Electricity Market Authority's (EMA) import tender. The output generation development plan from the TSIRP model is used as in input to 2-4-C.

2-4-C

2-4-C replicates market dispatch on a half-hourly basis and can be used to forecast the Singapore wholesale electricity market for a 30-year time-horizon under multiple scenarios. The model takes input data and assumptions relating to supply and demand and generates many outputs including generation outcomes, wholesale prices and electricity sector emissions.