SERIS
Solar Energy Research Institute of Singapore

Solar Economics Handbook of Singapore

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Solar Energy Research Institute of Singapore (SERIS)

Singapore, 19 December 2019

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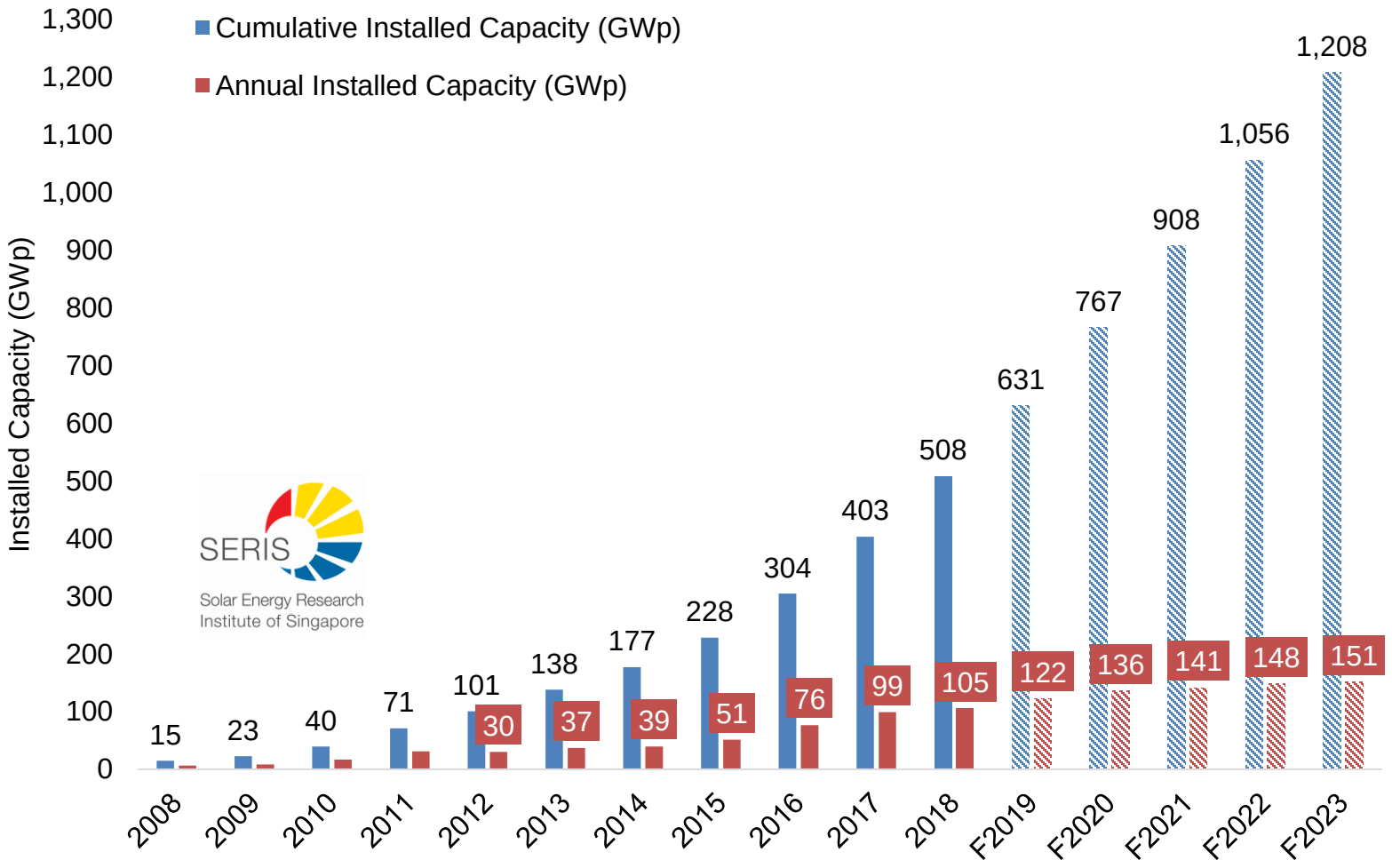
Overview

1. Global PV market
2. Singapore PV market
3. Singapore electricity market
   a) Structure
   b) Generation
   c) Demand
   d) Prices
4. PV adoption in Singapore
5. Future electricity price scenarios
6. Grid parity and economic viability analysis

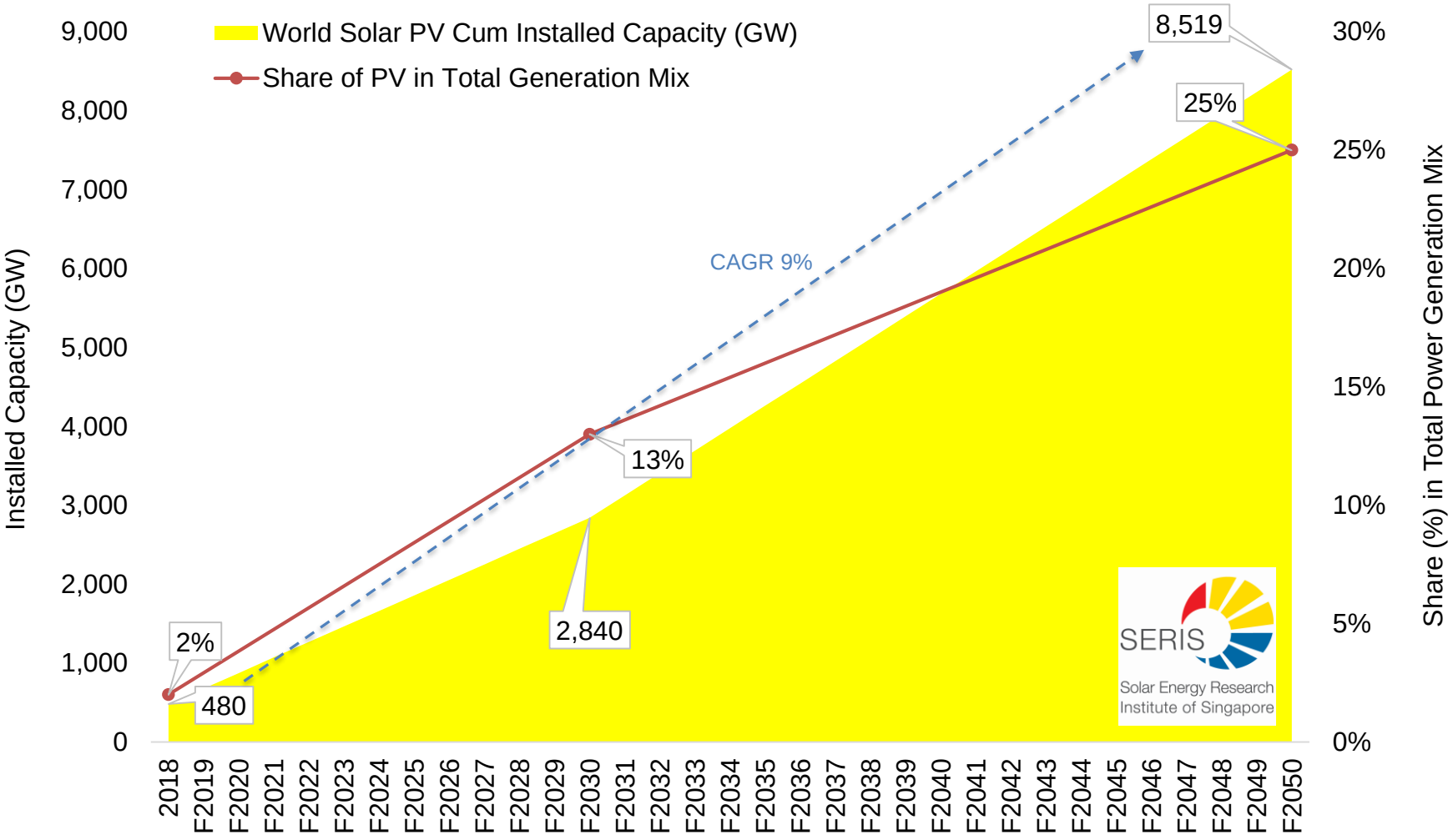
1. Global PV market

Global PV installed capacity



Data source: 2008-2017: IEA PVPS and 2018-2023: forecast based on different sources (IHS, BNEF, SolarPower Europe, Wood Mackenzie, GCL and Energy Trend)

IRENA PV projections until 2050



Data source: IRENA REmap scenario 2019

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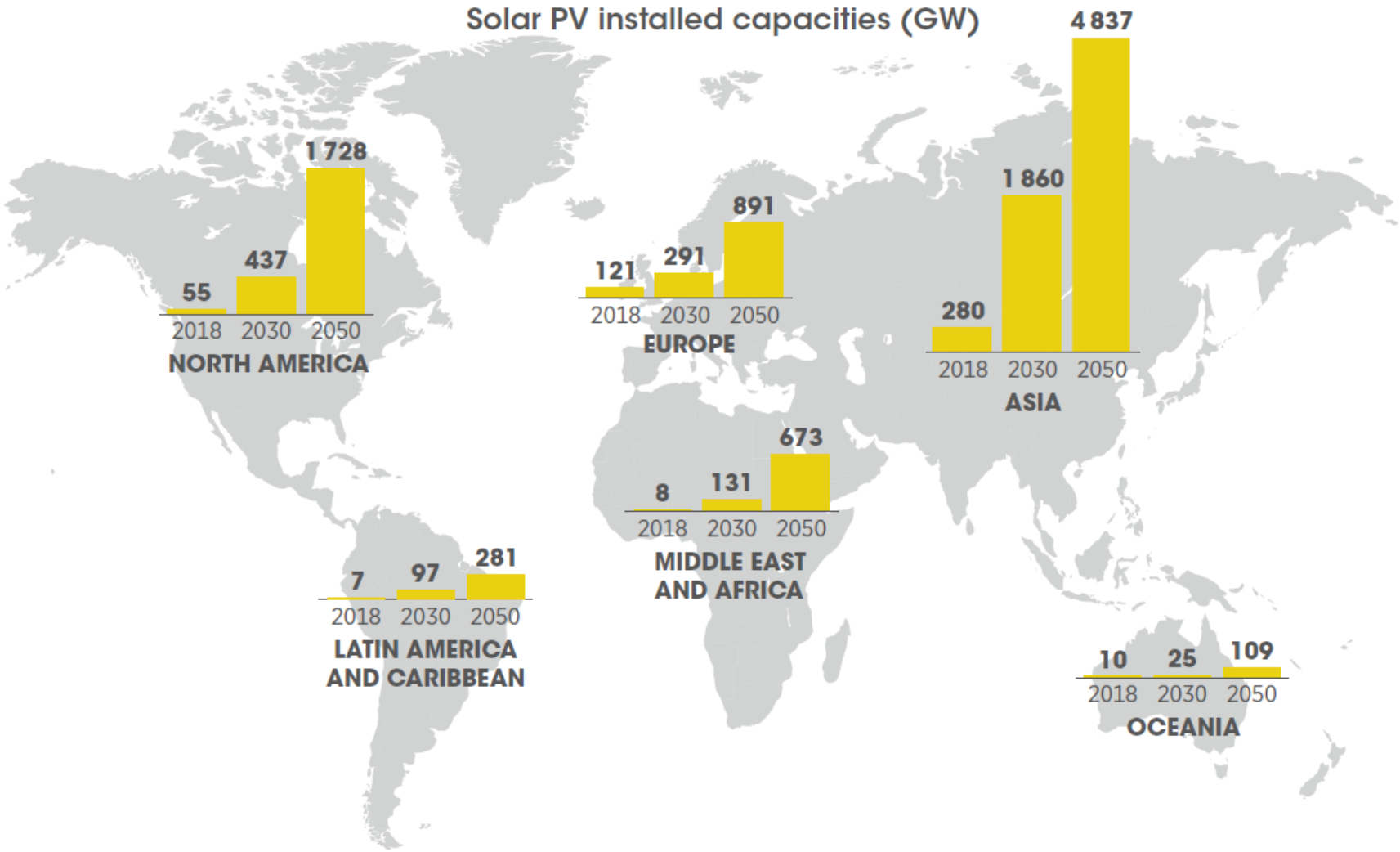
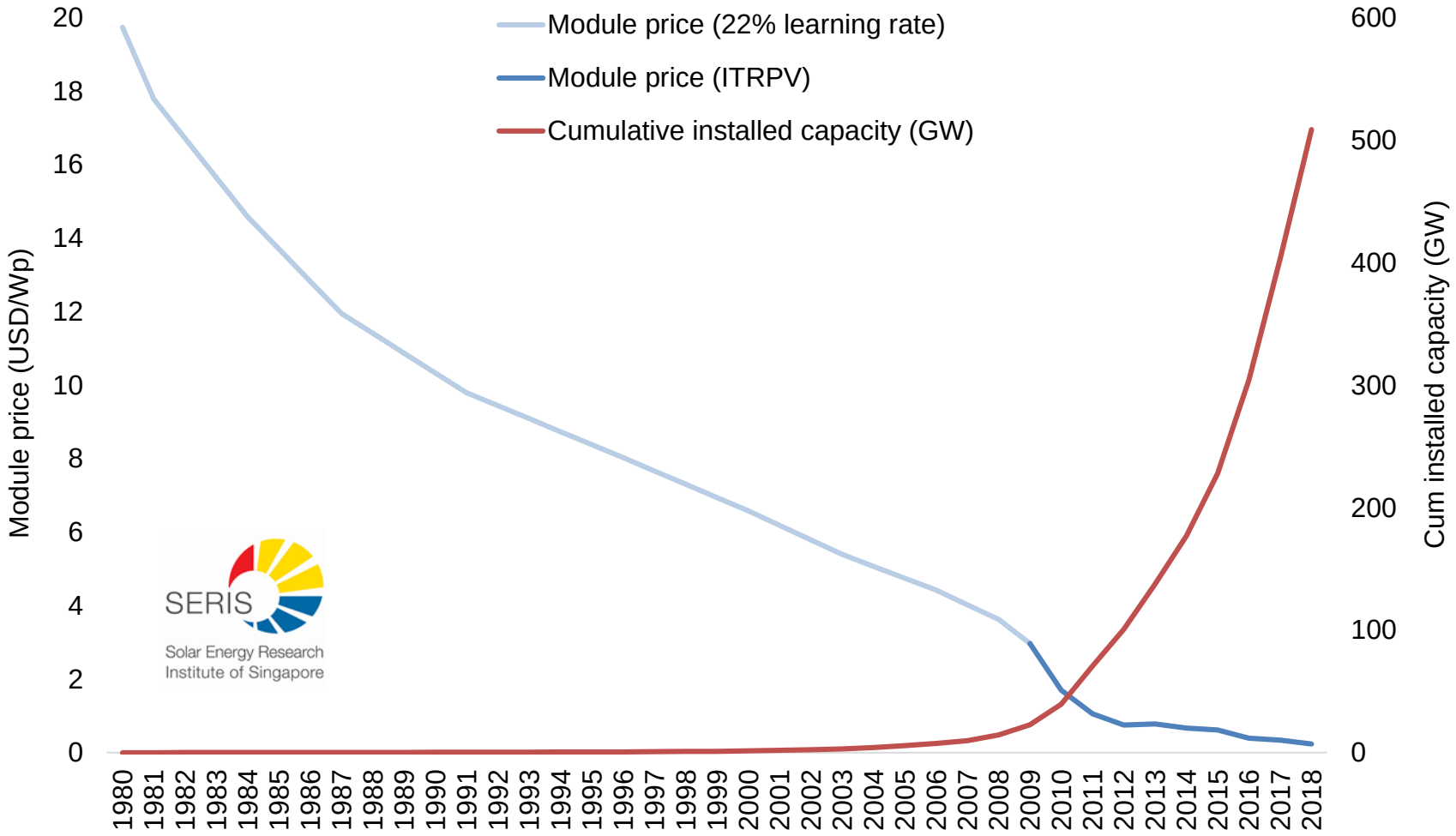
IRENA PV projections until 2050



Data source: IRENA REmap scenario 2019

Historic global PV module prices

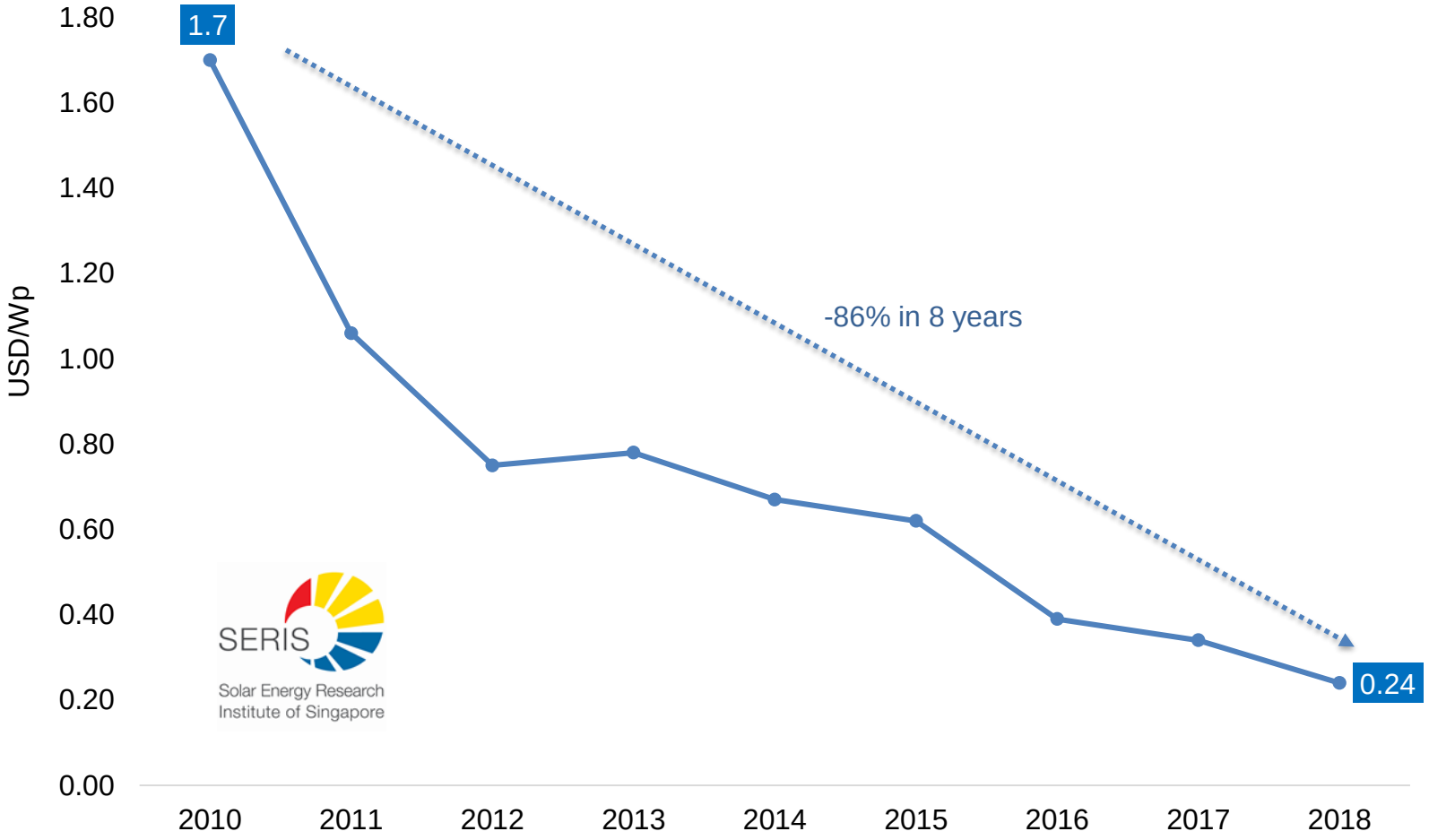
Reducing trend of module prices with increasing installed capacity



Data source: SERIS market research, ITRPV 10th edition (October 2019)

Recent history of PV module prices

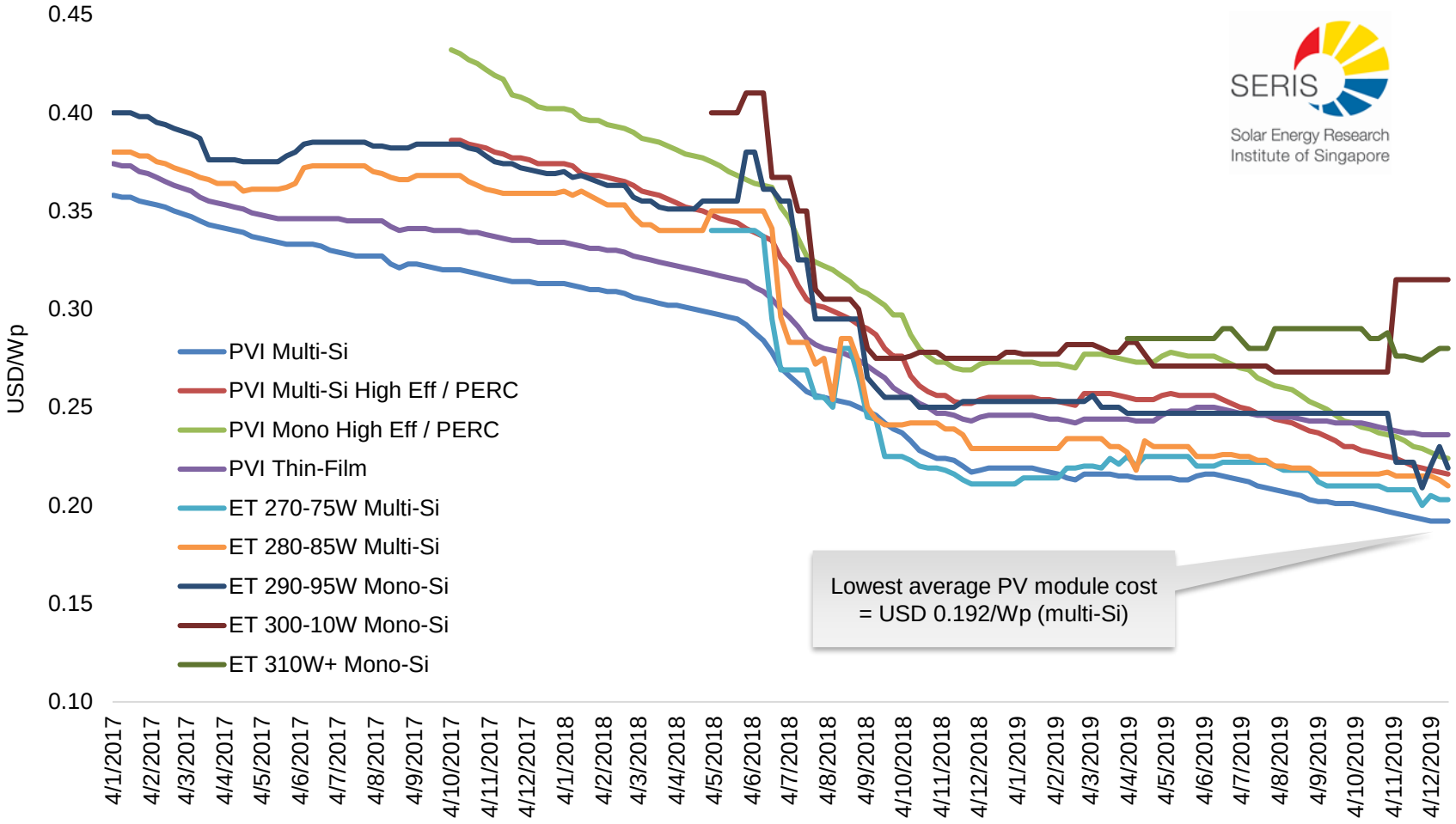
Yearly average USD spot prices for c-Si module



Data source: ITRPV 10th edition (October 2019)

Recent history of PV module prices

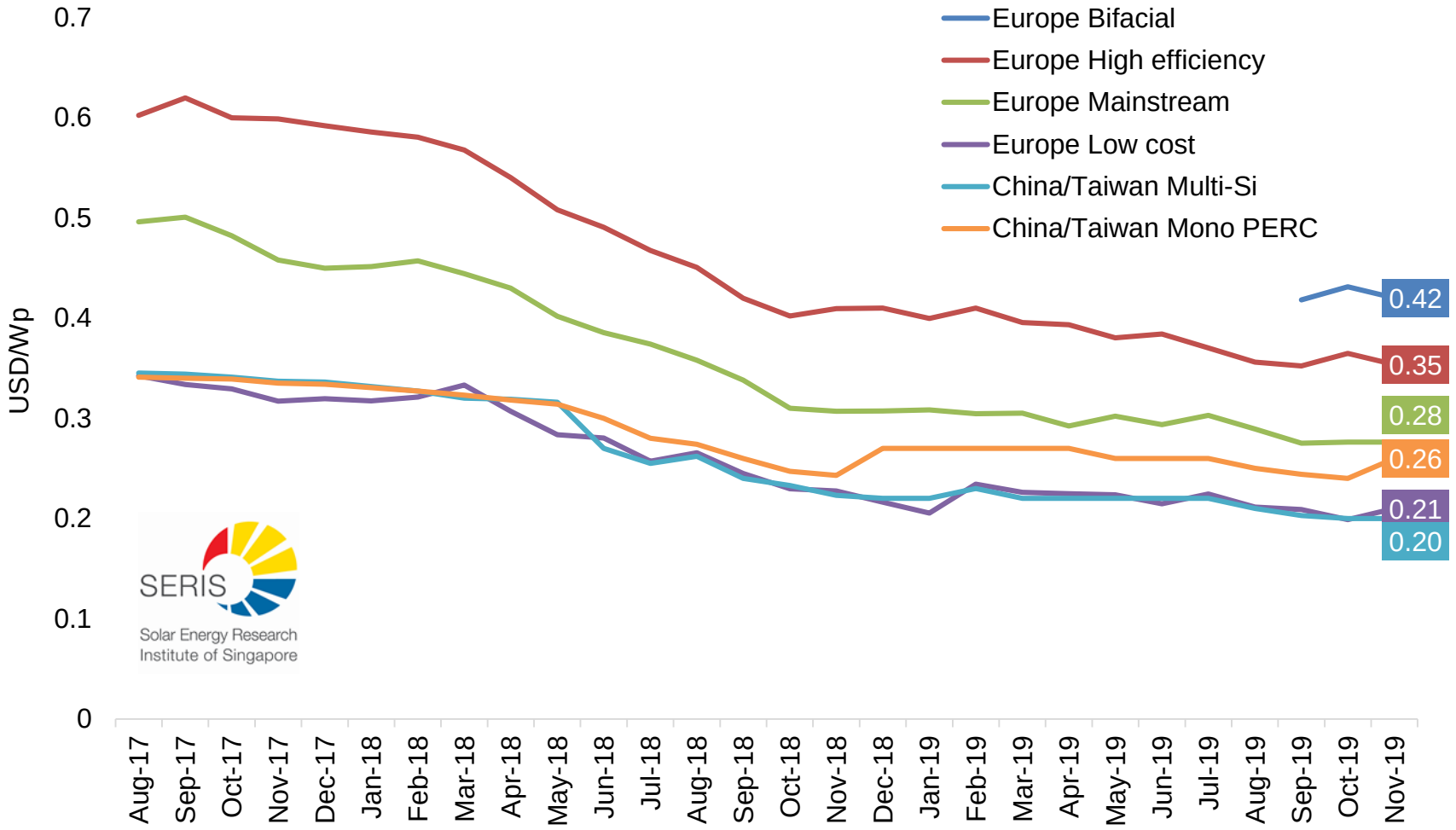
Average USD spot prices by module efficiency



Data source: PVinsights (PVI) and EnergyTrend (ET)

Recent history of PV module prices

Monthly average USD spot prices by region and efficiency



Data source: Mercom (China/Taiwan), SolarServer & pvXchange (Europe)

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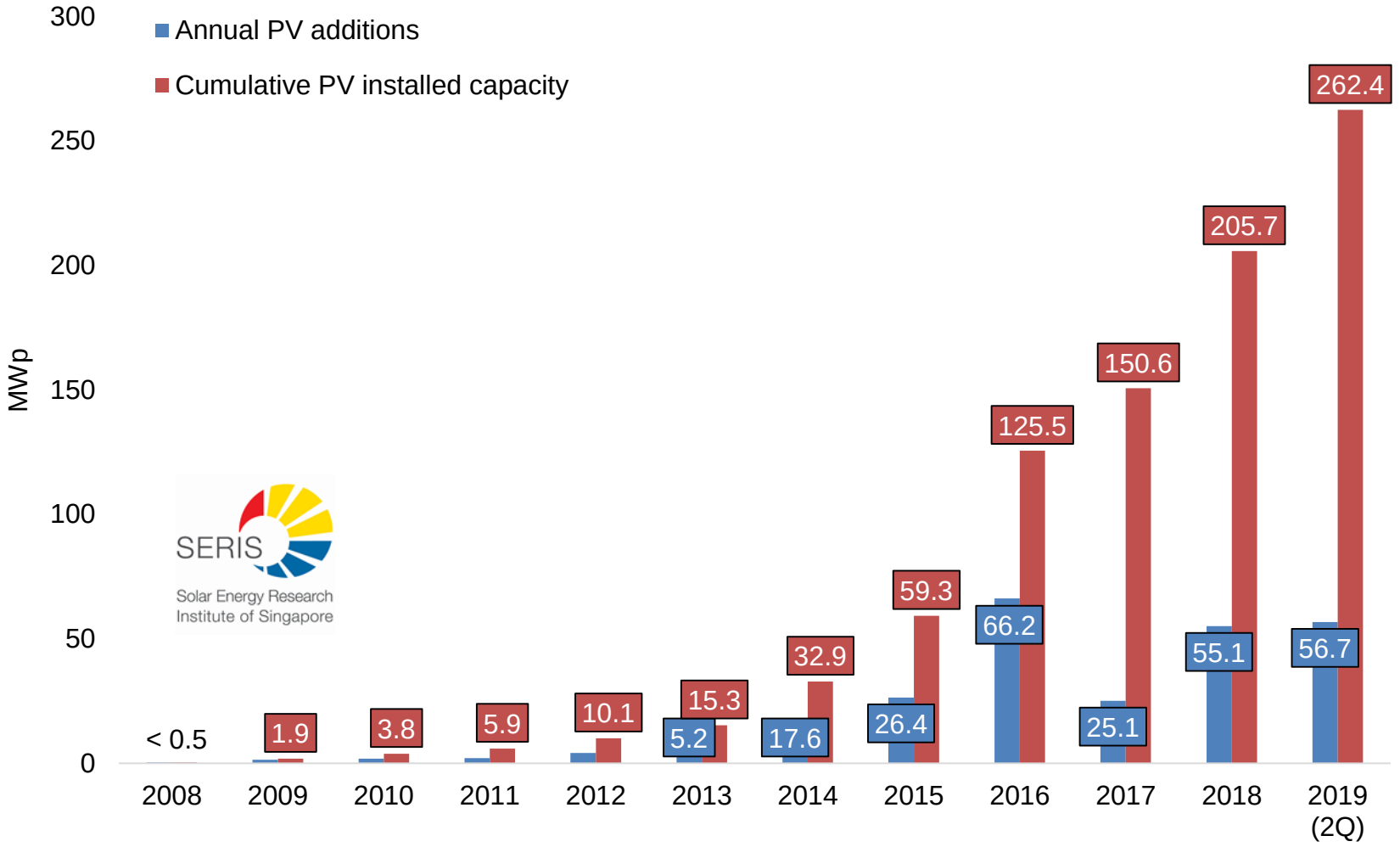
2. Singapore PV market

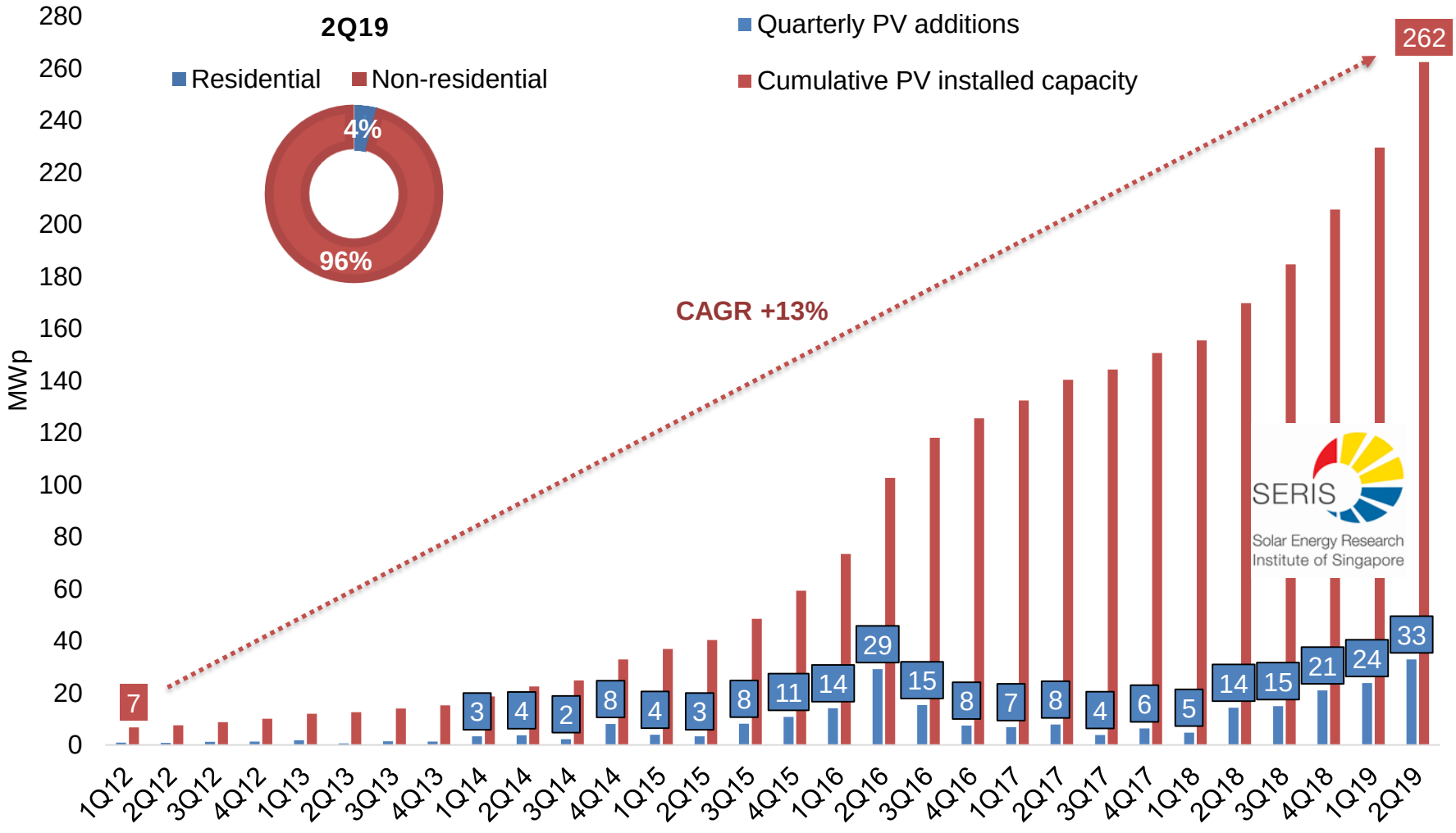
Installed capacity in Singapore today

Annual statistics



Data source: EMA (SP PowerGrid Ltd)

Latest quarterly statistics



Data source: EMA (SP PowerGrid Ltd)

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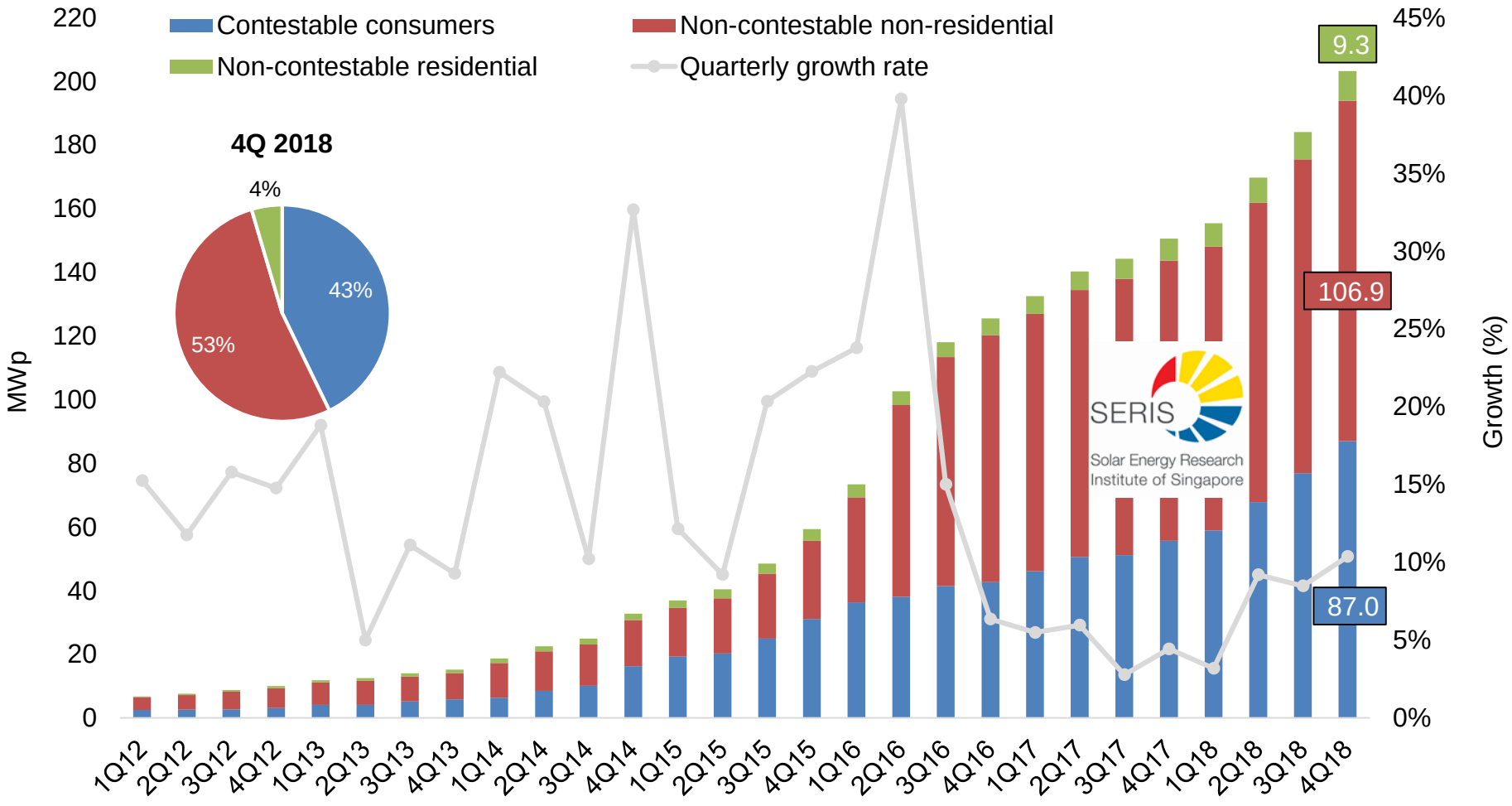
Quarterly PV installation growth rate

53% share: non-contestable non-residential (mainly HDB blocks)



Data source: EMA (SP PowerGrid Ltd). Data after 4Q18 no longer available following OEM

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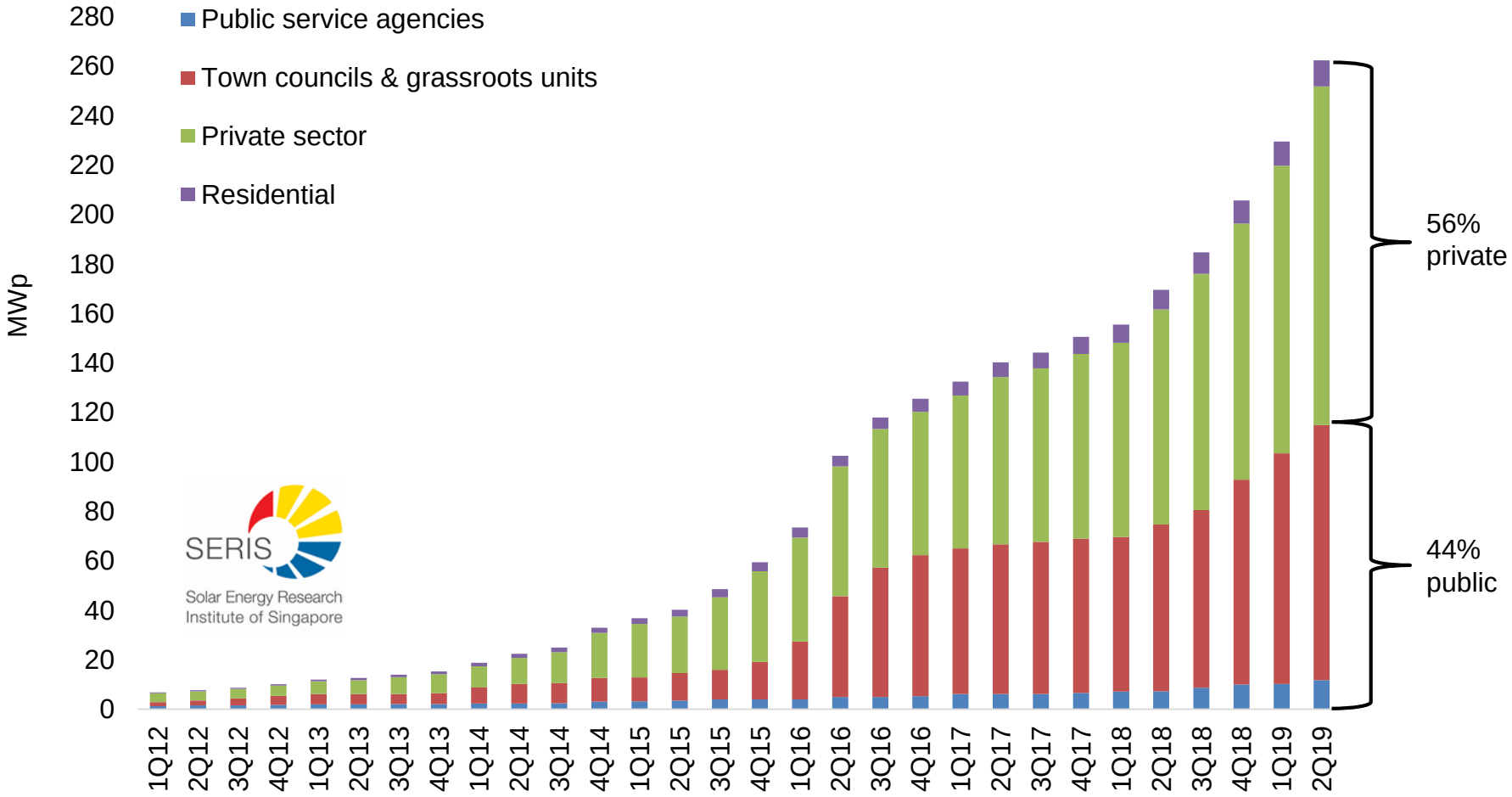
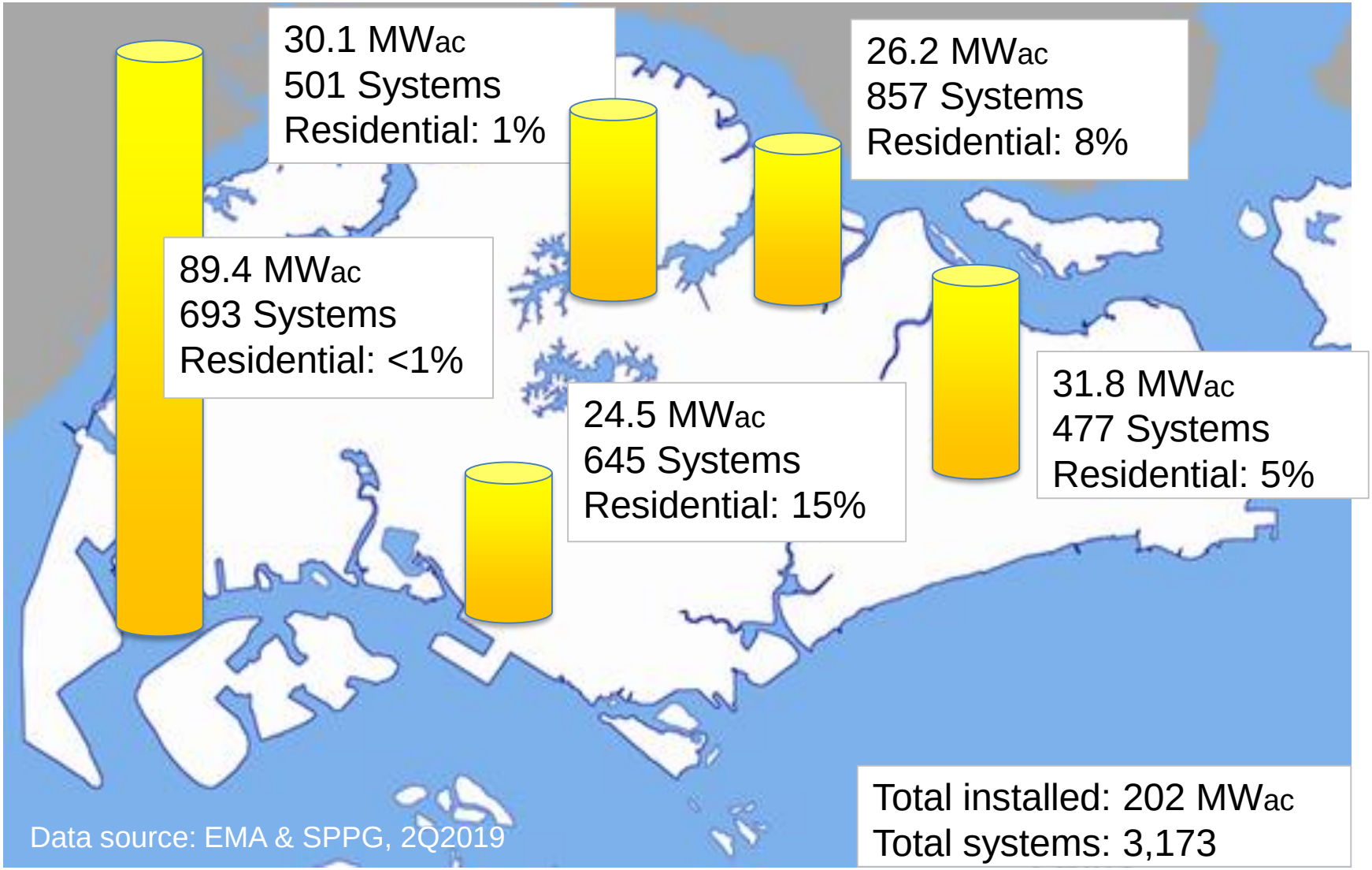
PV installation by user type

Public sector 44%, private sector 56%

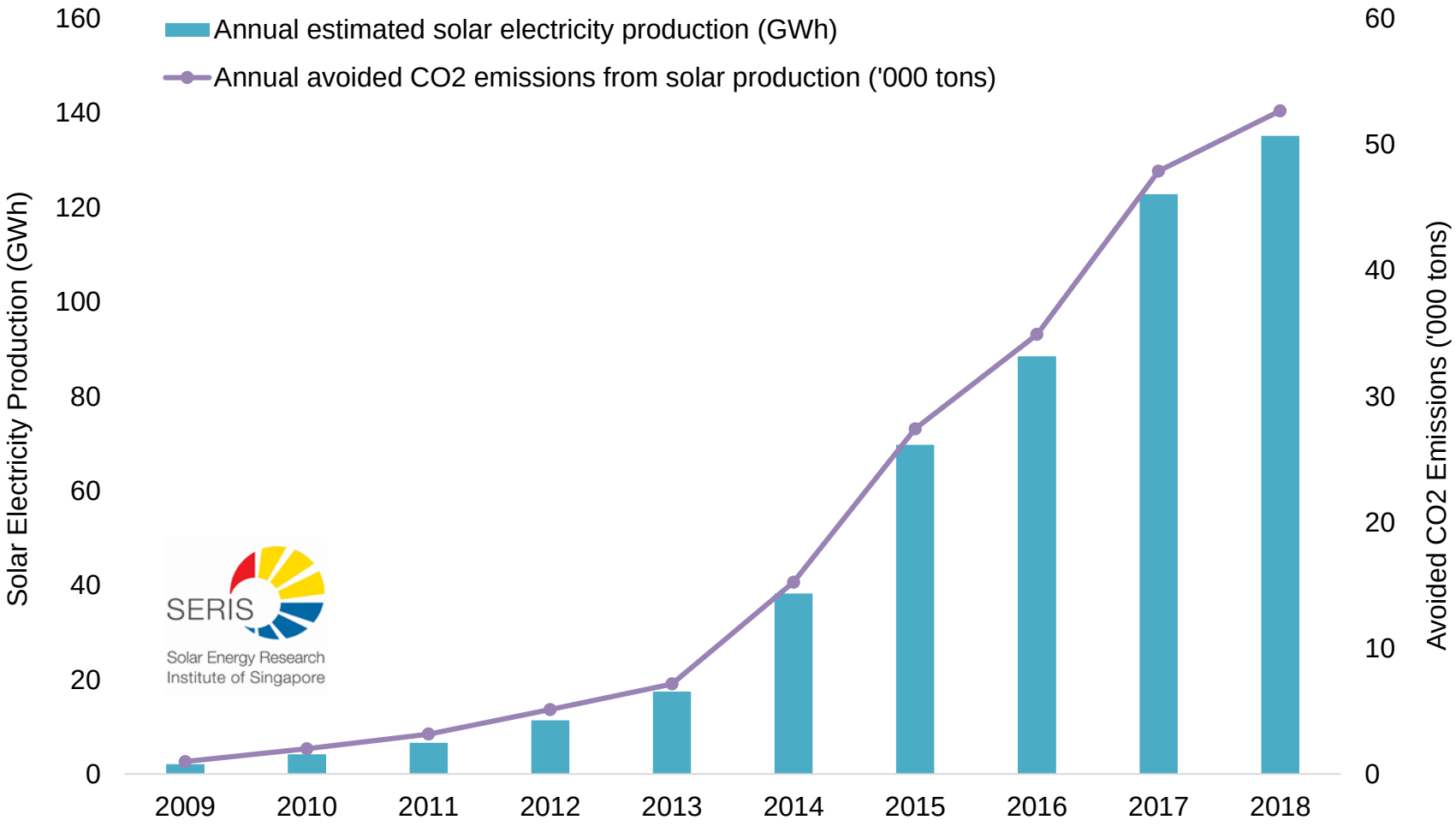


Data source: EMA (SP PowerGrid Ltd)

Regional split within Singapore [MWac]



Annually avoided CO_2 emissions



Data source: EMA for annual grid emission factor, Wei Luo et all 2018 for the carbon footprint of solar PV rooftops (deducted at 29.2 gCO_2/kWh), EMA for solar electricity production (2016-2018)

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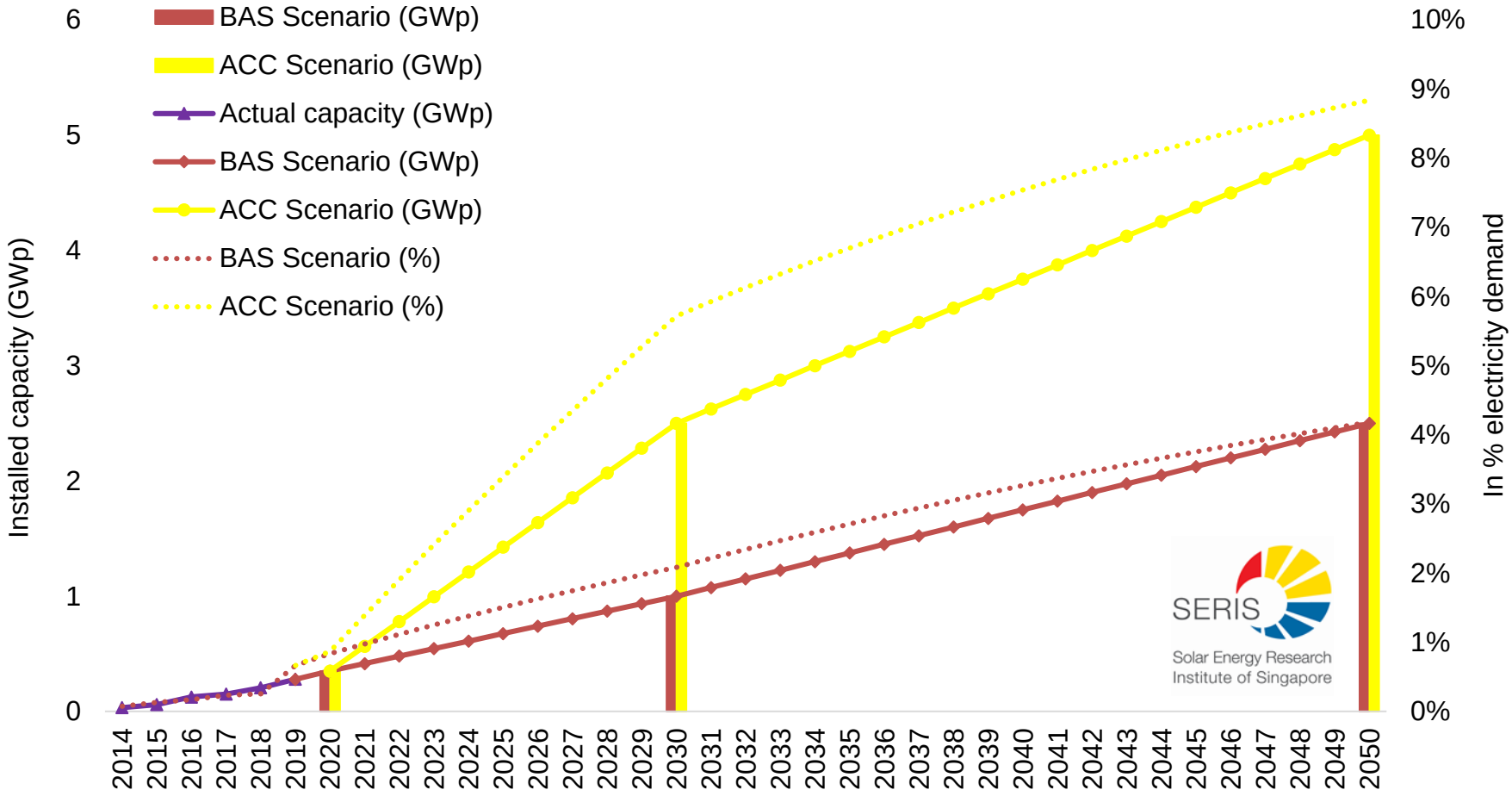
Future solar PV potential

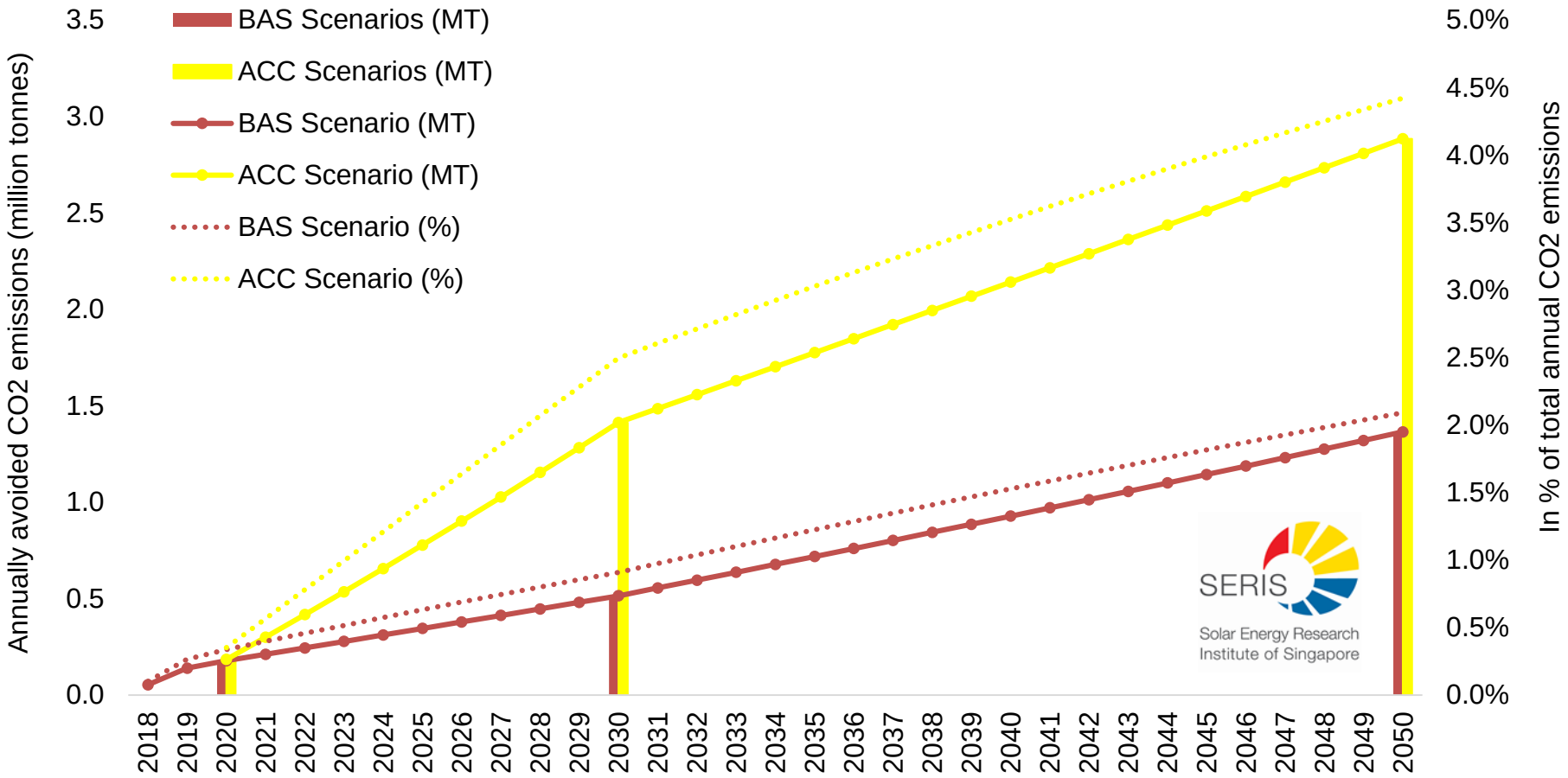
~3-6% of total electricity demand



Data source: 2019 Solar PV Roadmap update, annual electricity demand: EMA – SEMO 2019 (lower range; growth assumption = 1.4% after 2030)

Future annually avoided CO_2 potential

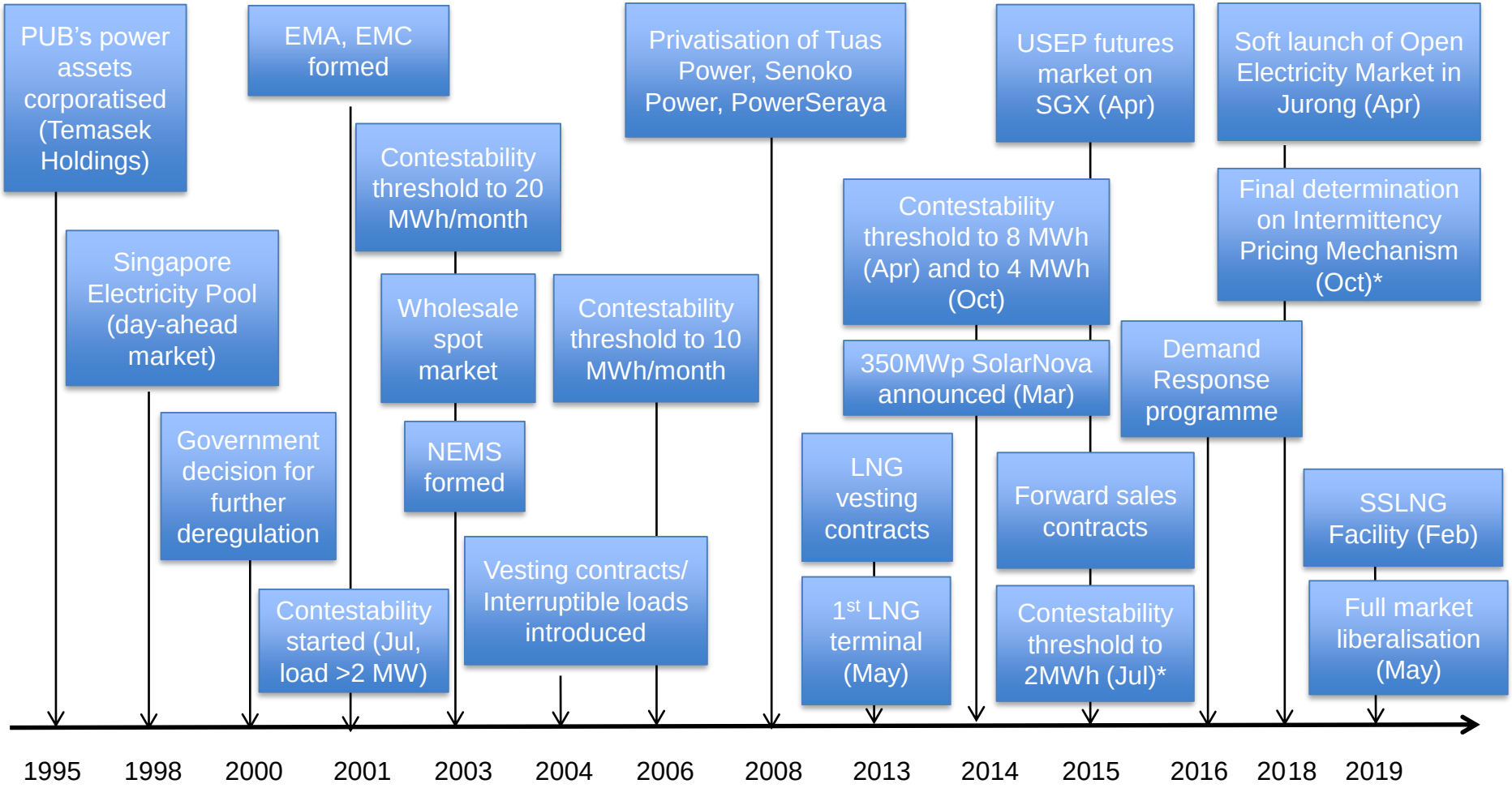
~0.7-1.6 million tonnes per annum



Data source: 2019 Solar PV Roadmap update, grid emission factor: 418.8 gCO_2/kWh (EMA, 2018), deducted 29.2 gCO^2/kWh as carbon footprint of solar PV rooftops, Singapore's CO_2 emission: 52 MT (2018), +1% p.a.

3a) Singapore electricity market: Structure

Milestones of Singapore Power Market



*To be implemented around 2020

Data source: SERIS based on EMC and EMA

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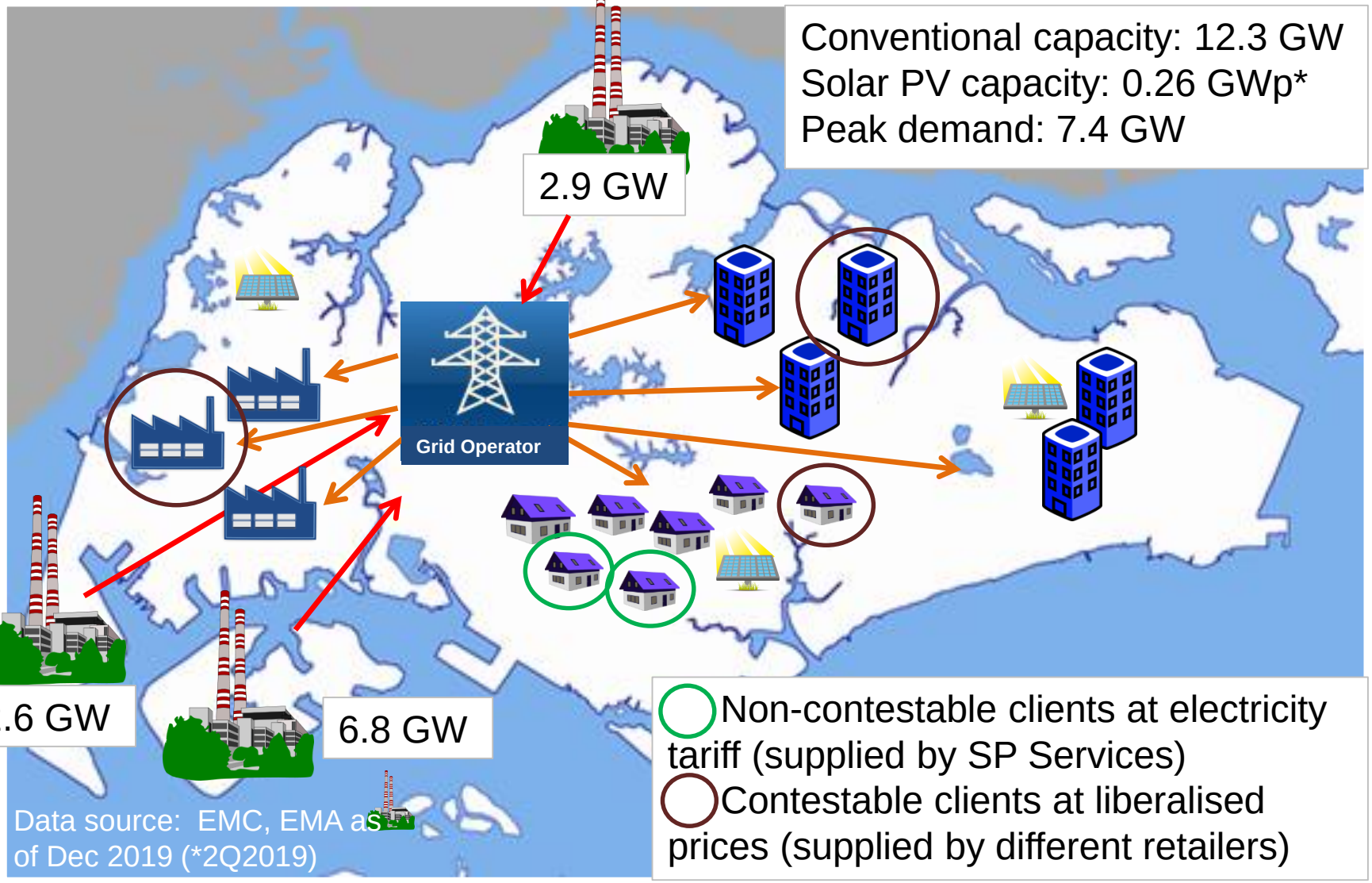
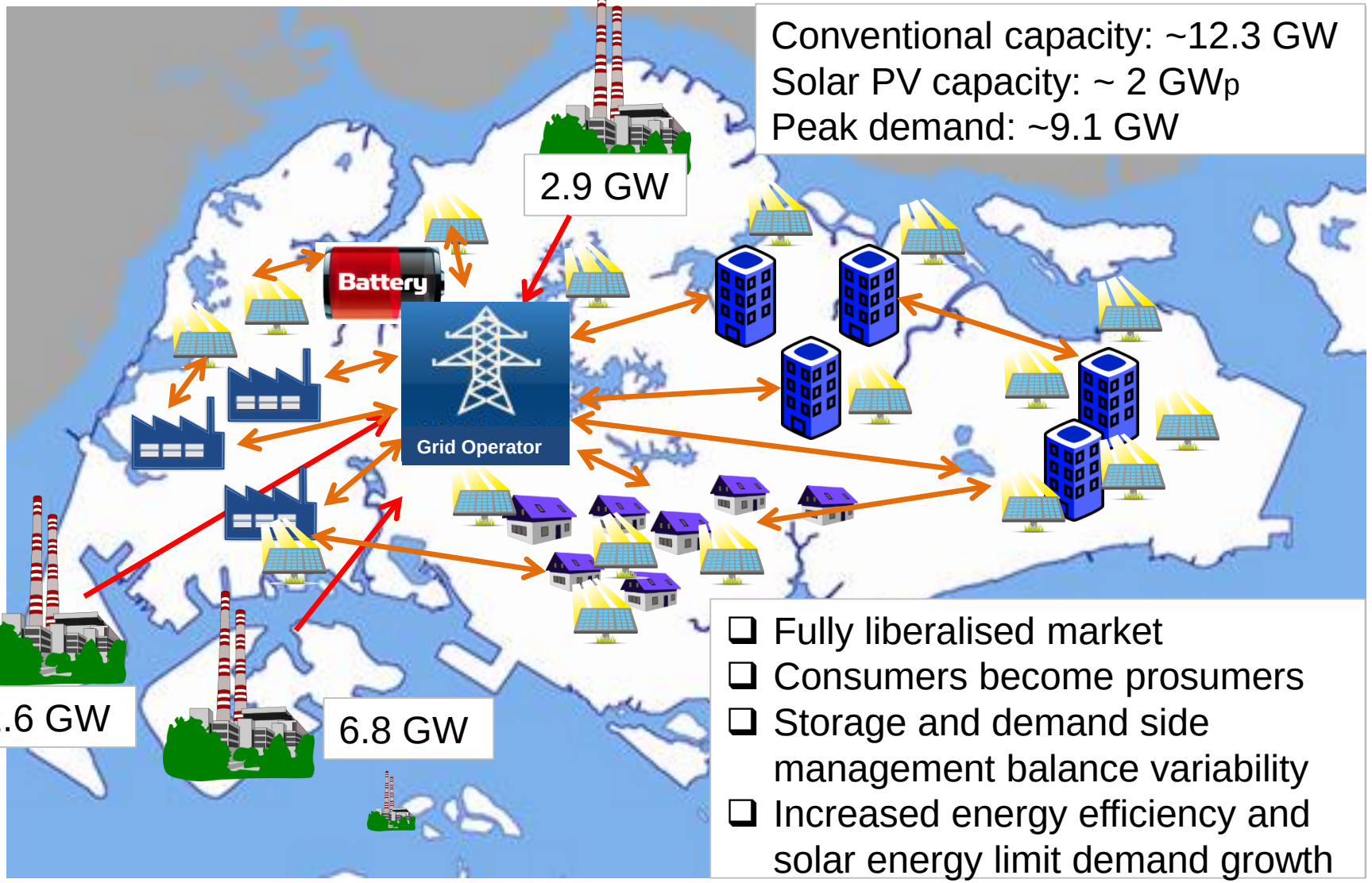
Electricity Industry Structure of Today



Example of Possible Structure by 2030



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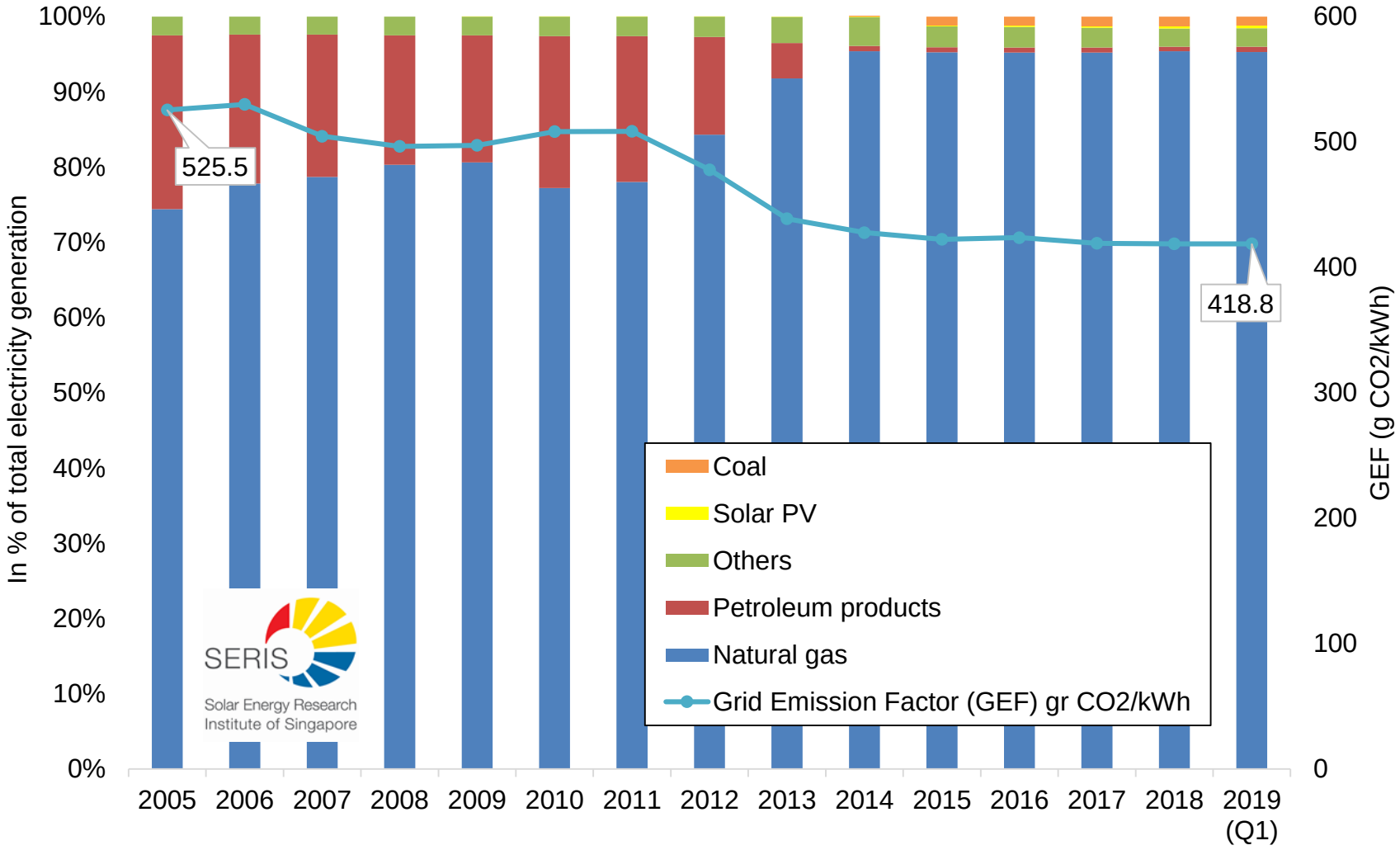
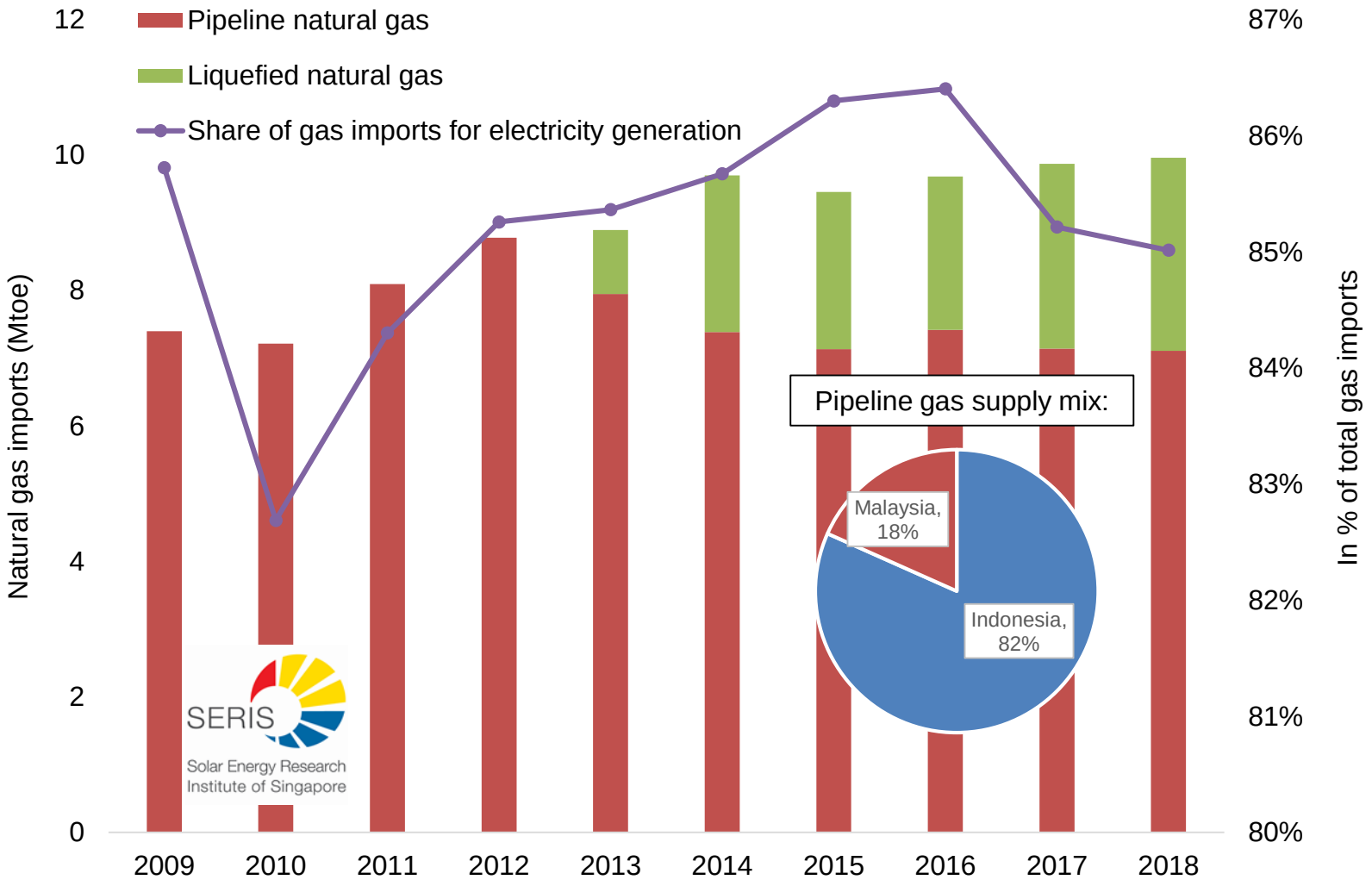
3b) Singapore electricity market: Generation

Power generation mix: 95% NG



Data source: EMA. GEF based on the average operating margin

Natural gas supply



Data source: EMA (Singapore Energy Statistics 2019), ITC Trade Map for pipeline gas supply mix (2018)

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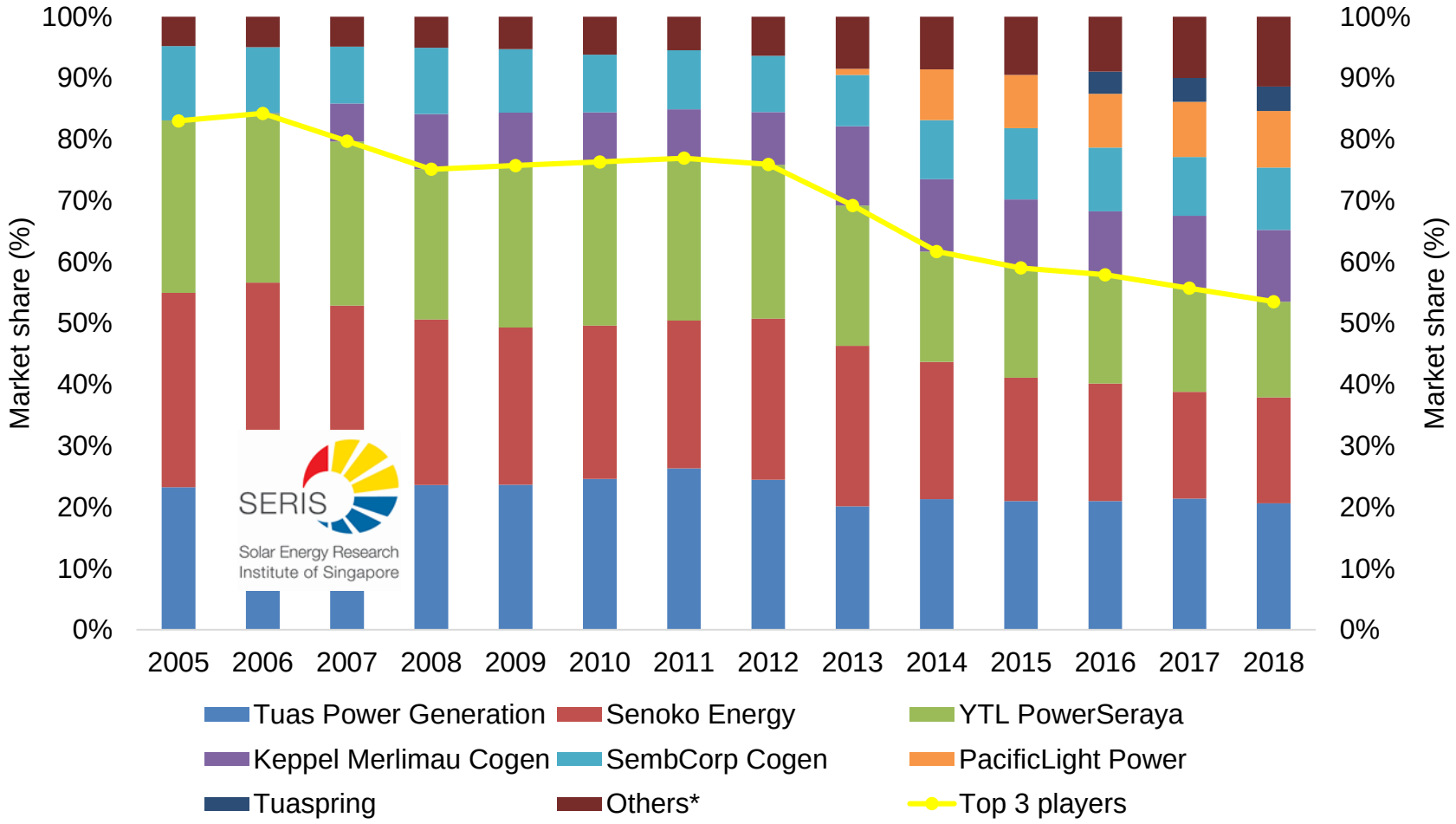
Development of market shares

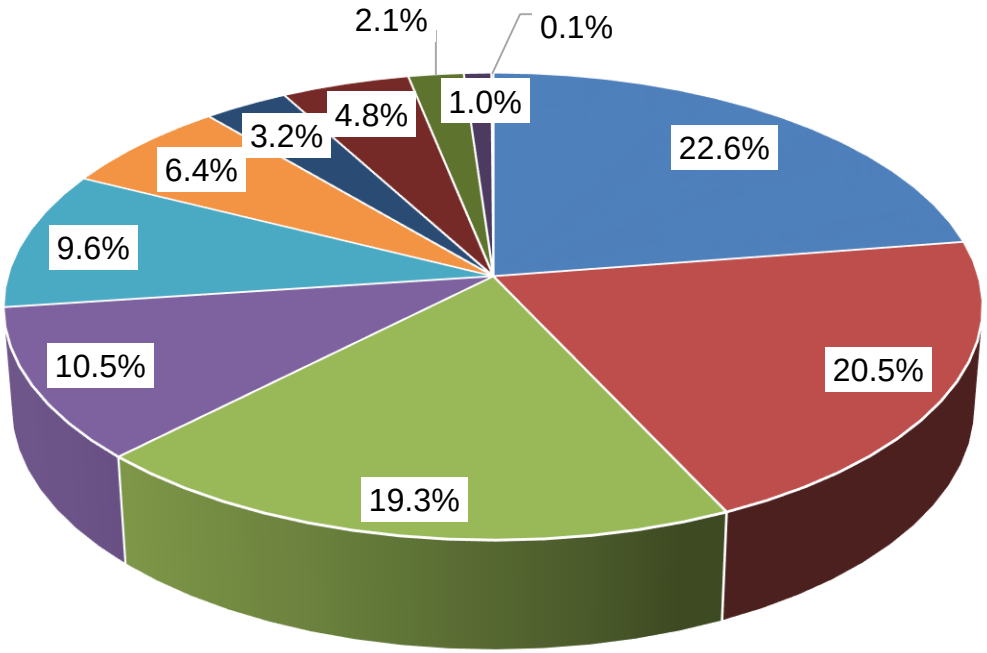
Based on scheduled electricity generation



*Include wholesale licensees, waste-to-energy plants and solar PV systems

Data source: EMA, EMC

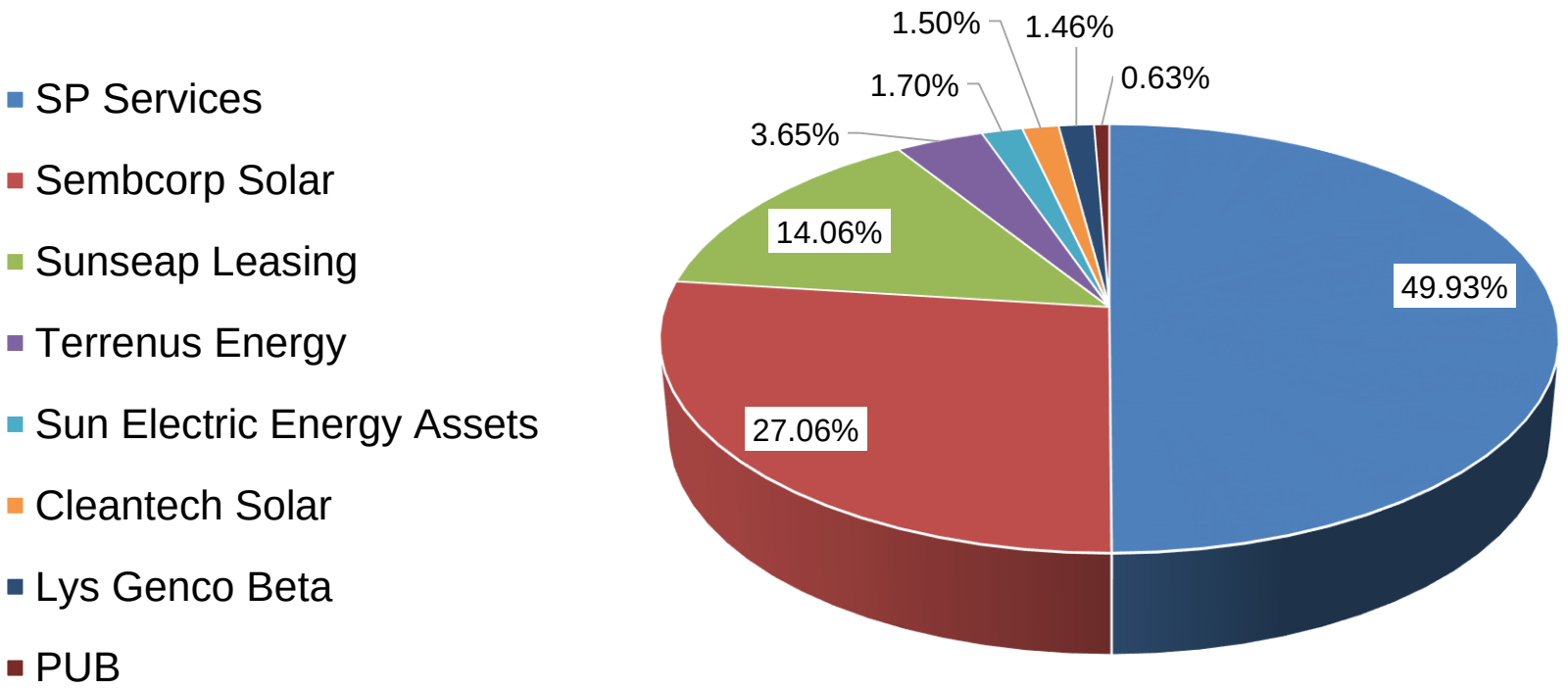
Market share of generation capacity



*SP Services and IGS owners are registering PV systems who chose EMC registration. As of 12 December 2019, registered IGS systems = 127 MW_{ac}. IGS = Intermittent Generation Sources
Data source: EMC. Total registered capacity of 12,440 MW as of 12 December 2019

Market share of IGS: 127.2 MWac*

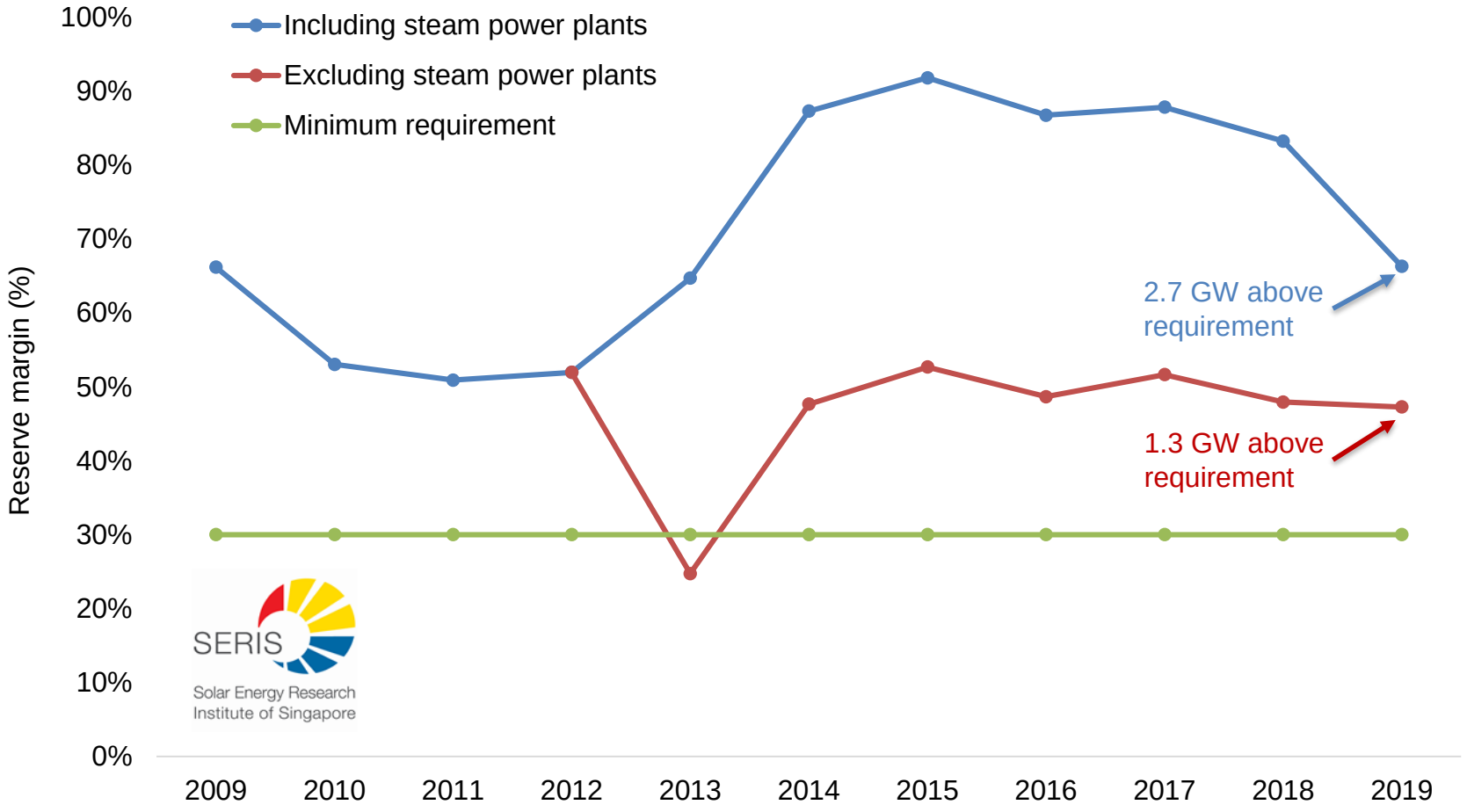
Includes only solar assets registered with EMC for exports (more than 70 MWac is not registered and not exporting to the grid)



*IGS = Intermittent Generation Sources
Comment: SP Services registers solar assets on behalf of asset owners in case < 10 MW_{ac}
Data source: EMC. IGS registered capacity as of 12 December 2019

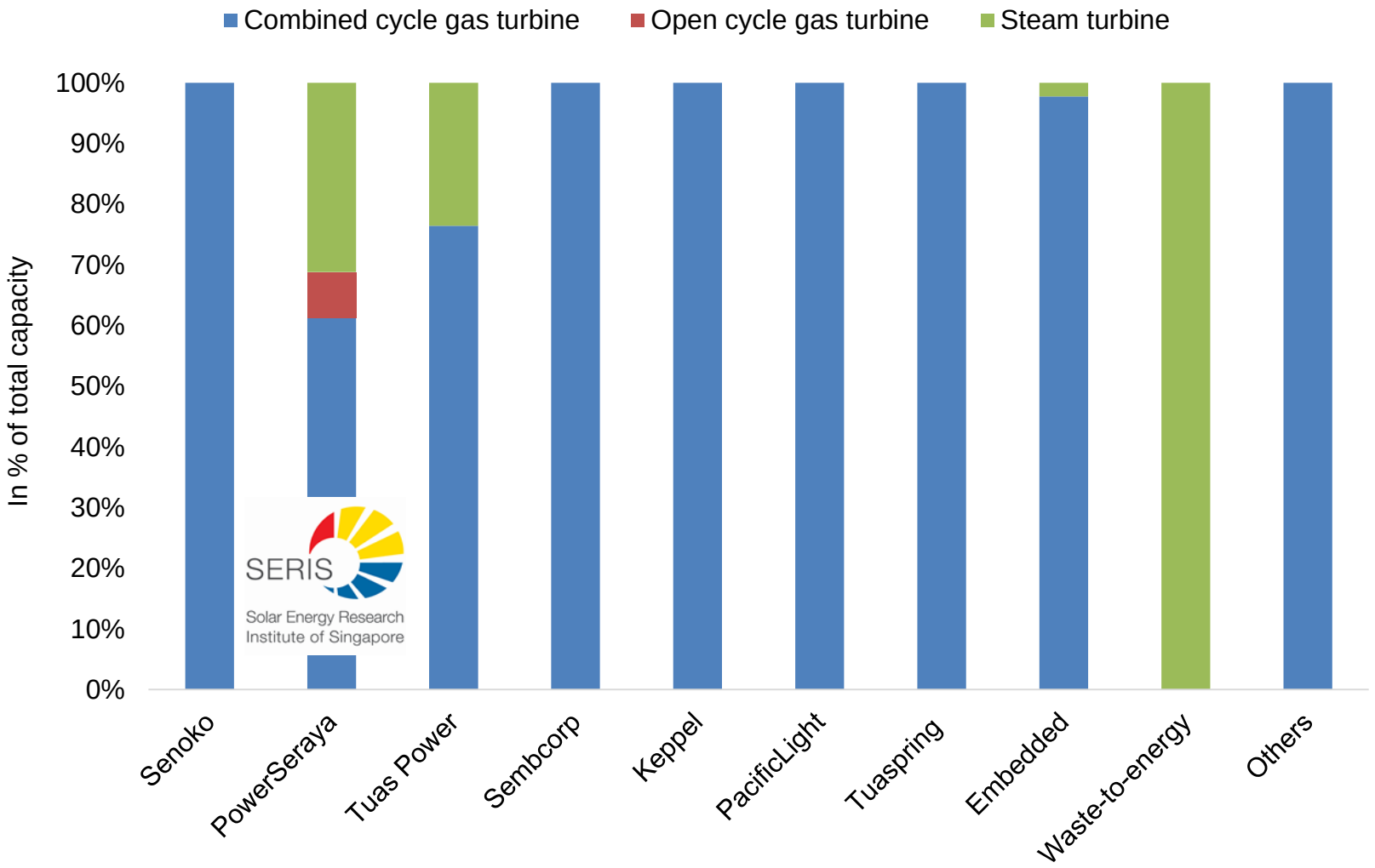
Historic system reserve margin

2013 onwards excluding steam turbine power plants



Data source: EMA for system peak demand, EMC for installed capacity (the latter does not consider grid transmission constraints)

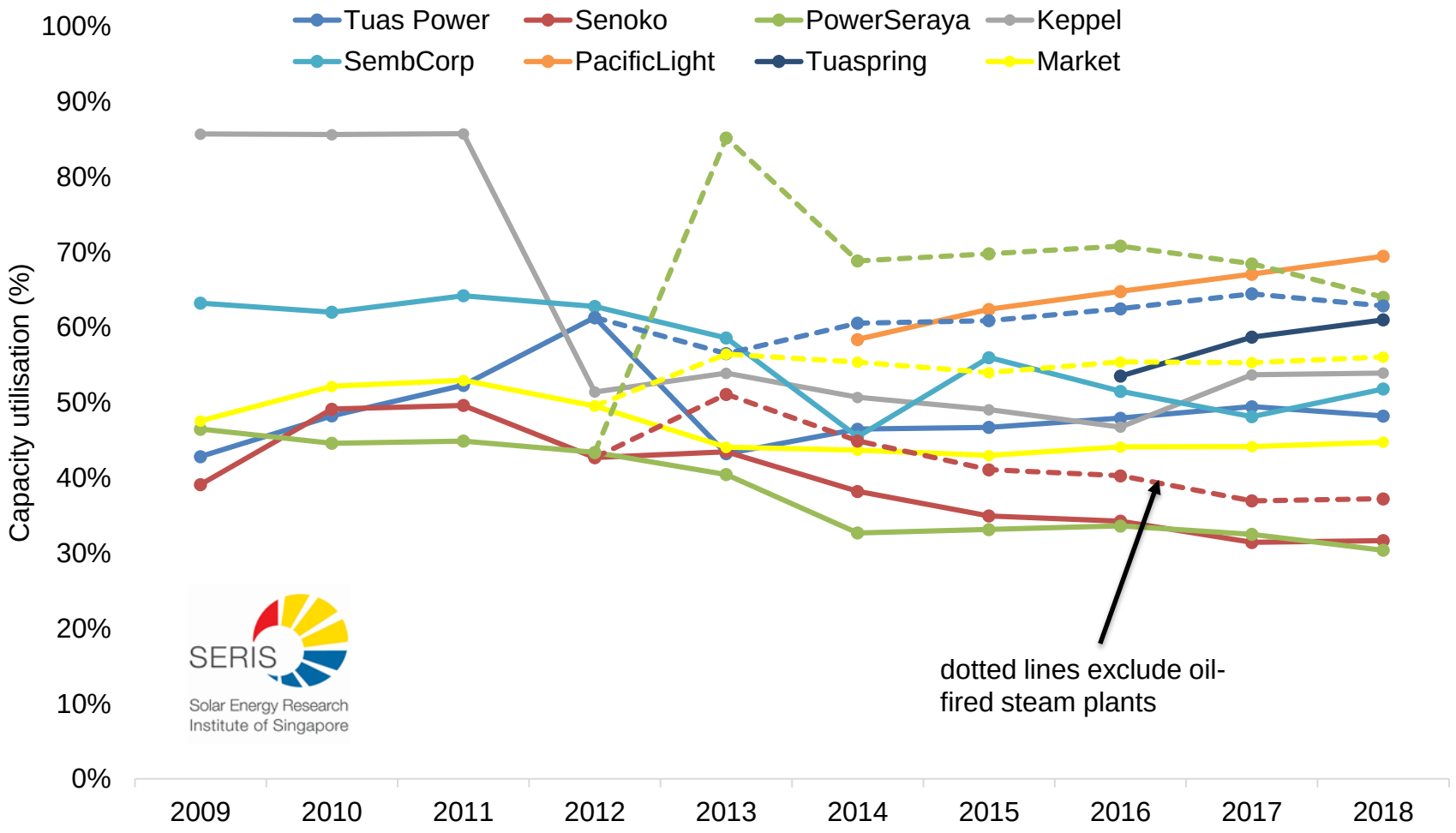
Conventional generators technology mix



Data source: EMC, as of 12 December 2019

Conventional capacity utilisation rate

Main generators compared to the market average



Data source: EMA

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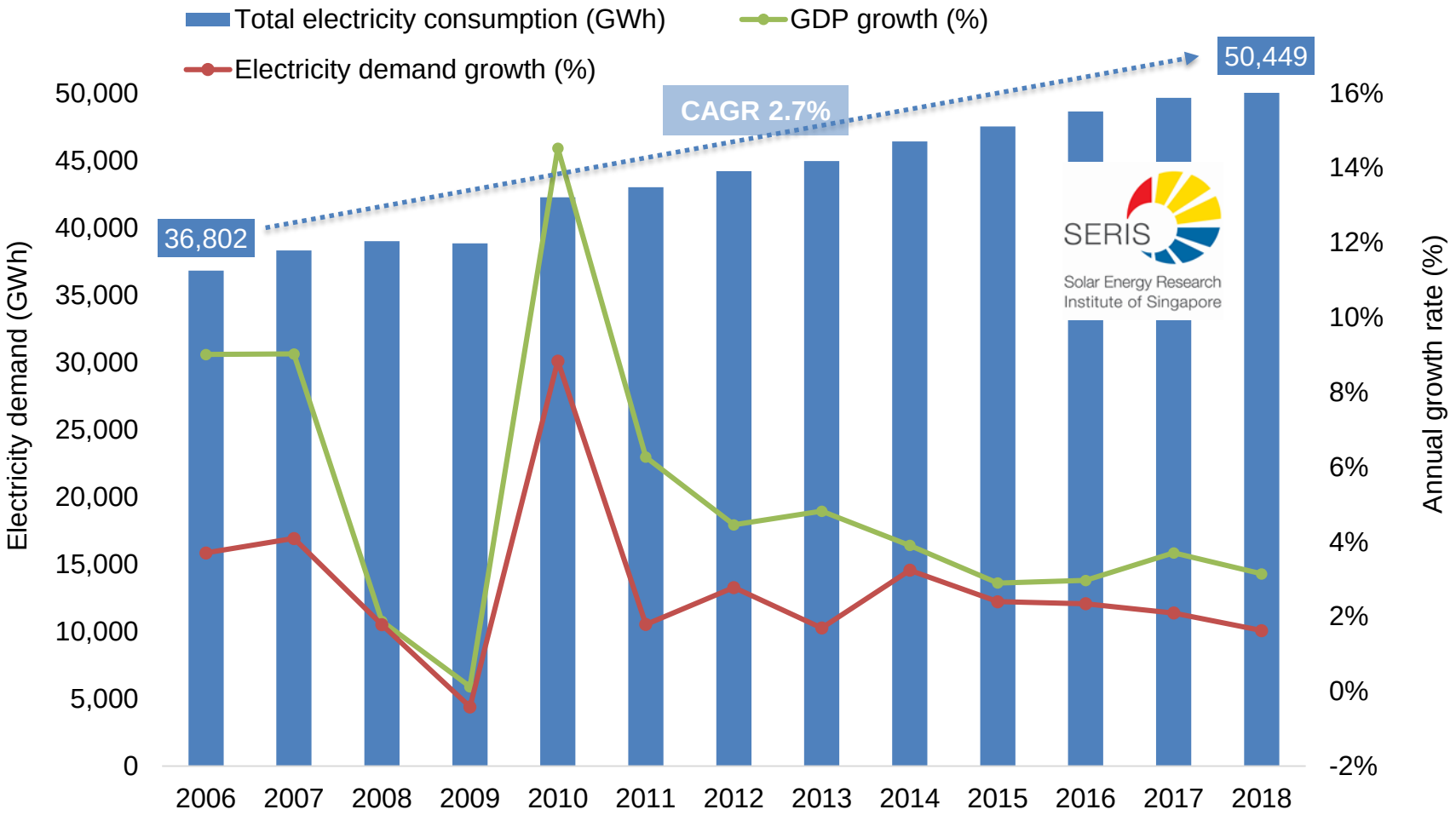
3c) Singapore electricity market: Demand

Electricity demand in Singapore

Demand growth compared to GDP growth



Data source: EMA, Ministry of Trade and Industry

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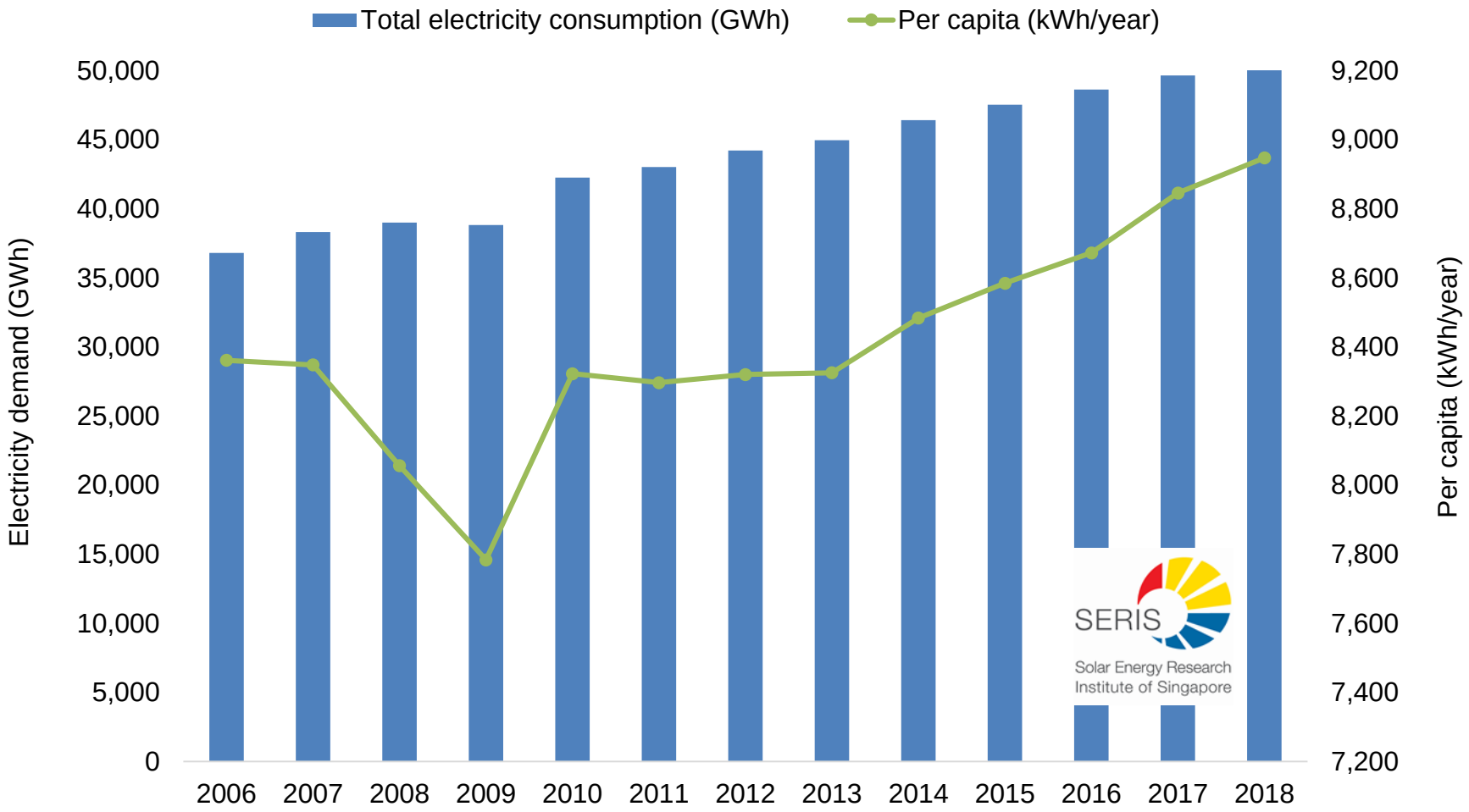
Electricity demand per capita

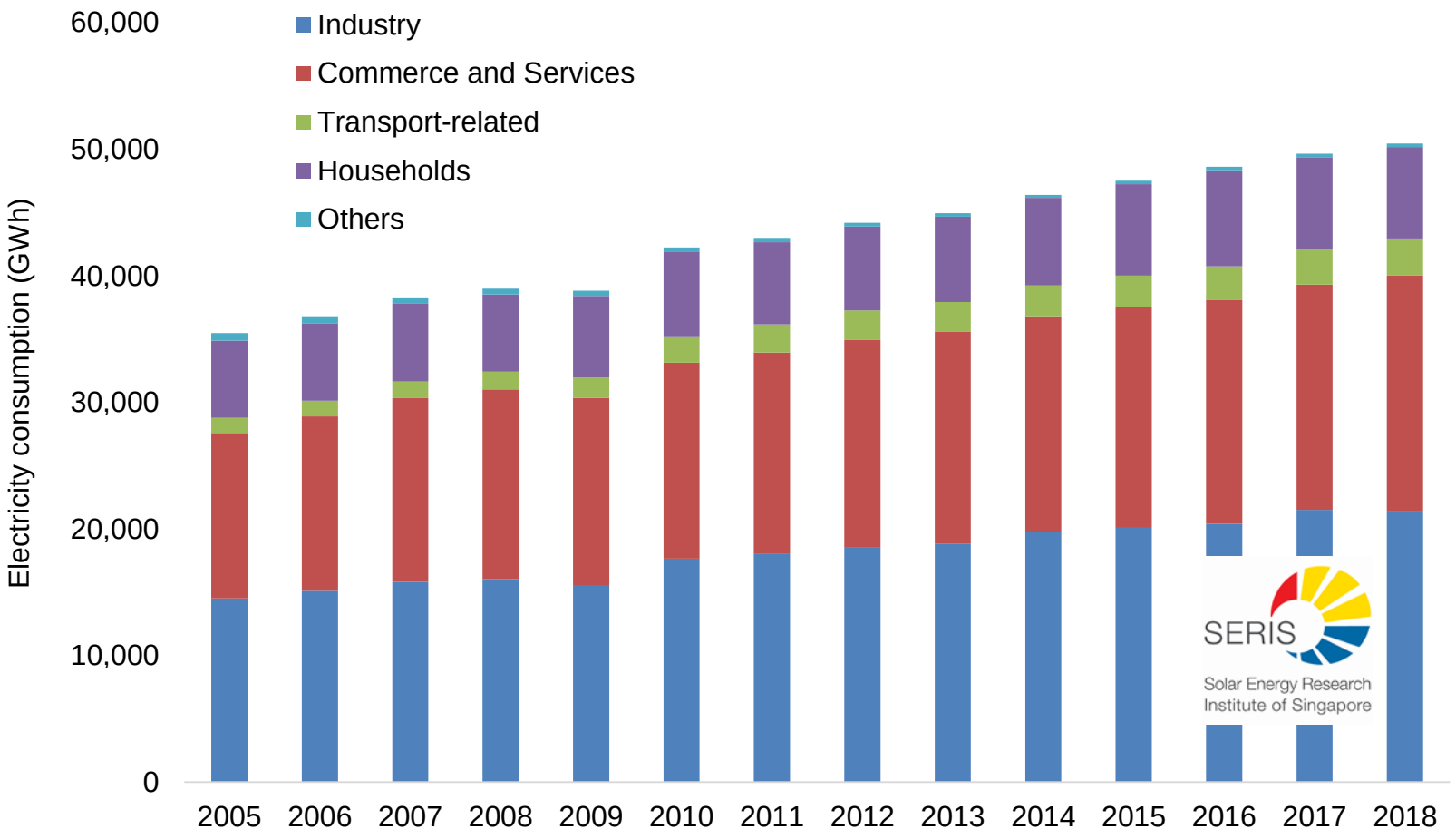
CAGR 2006-2018 = 0.6%



Data source: EMA, Singapore Department of Statistics

Electricity consumption mix

Break-down by usage



Data source: EMA

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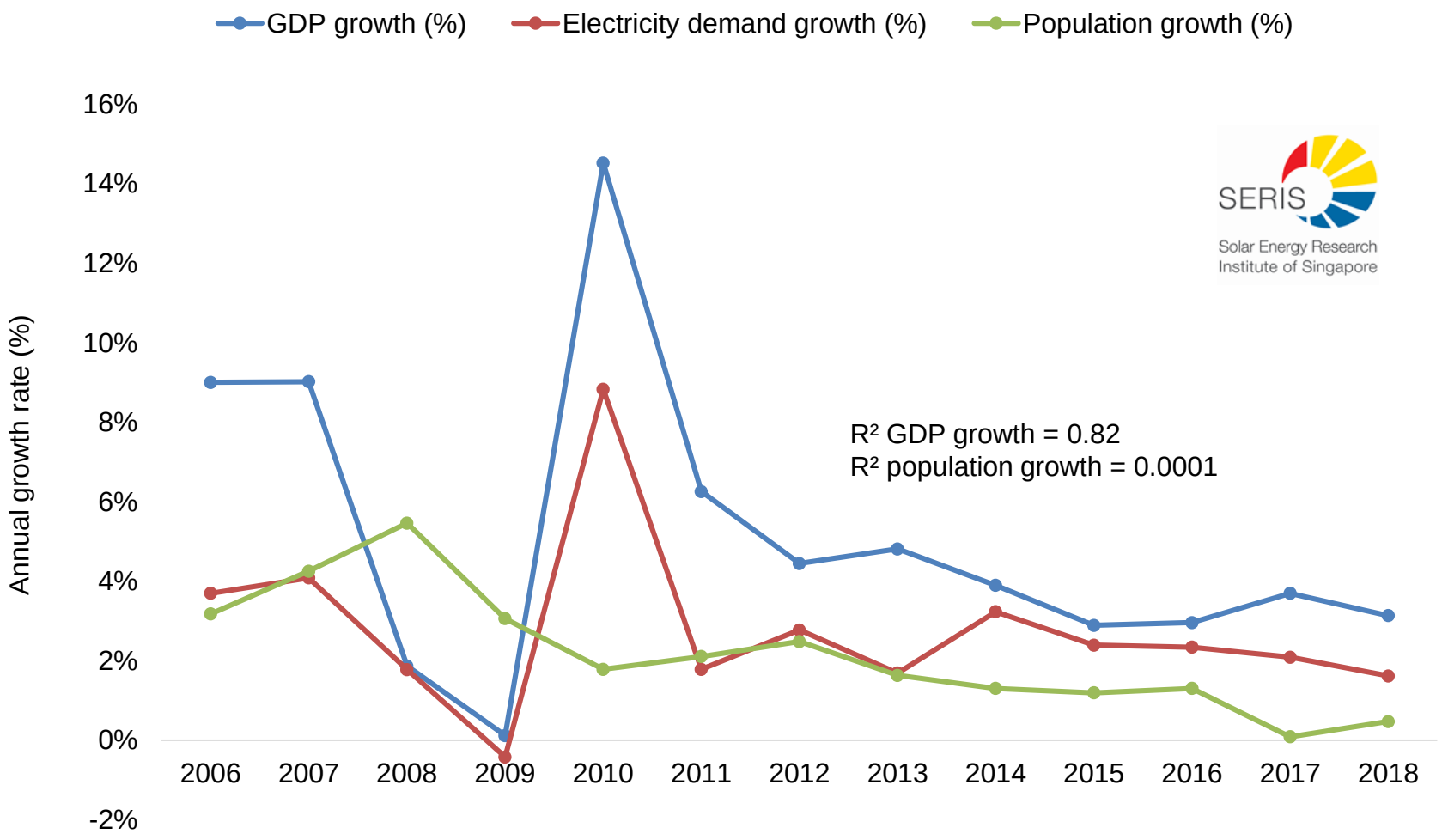
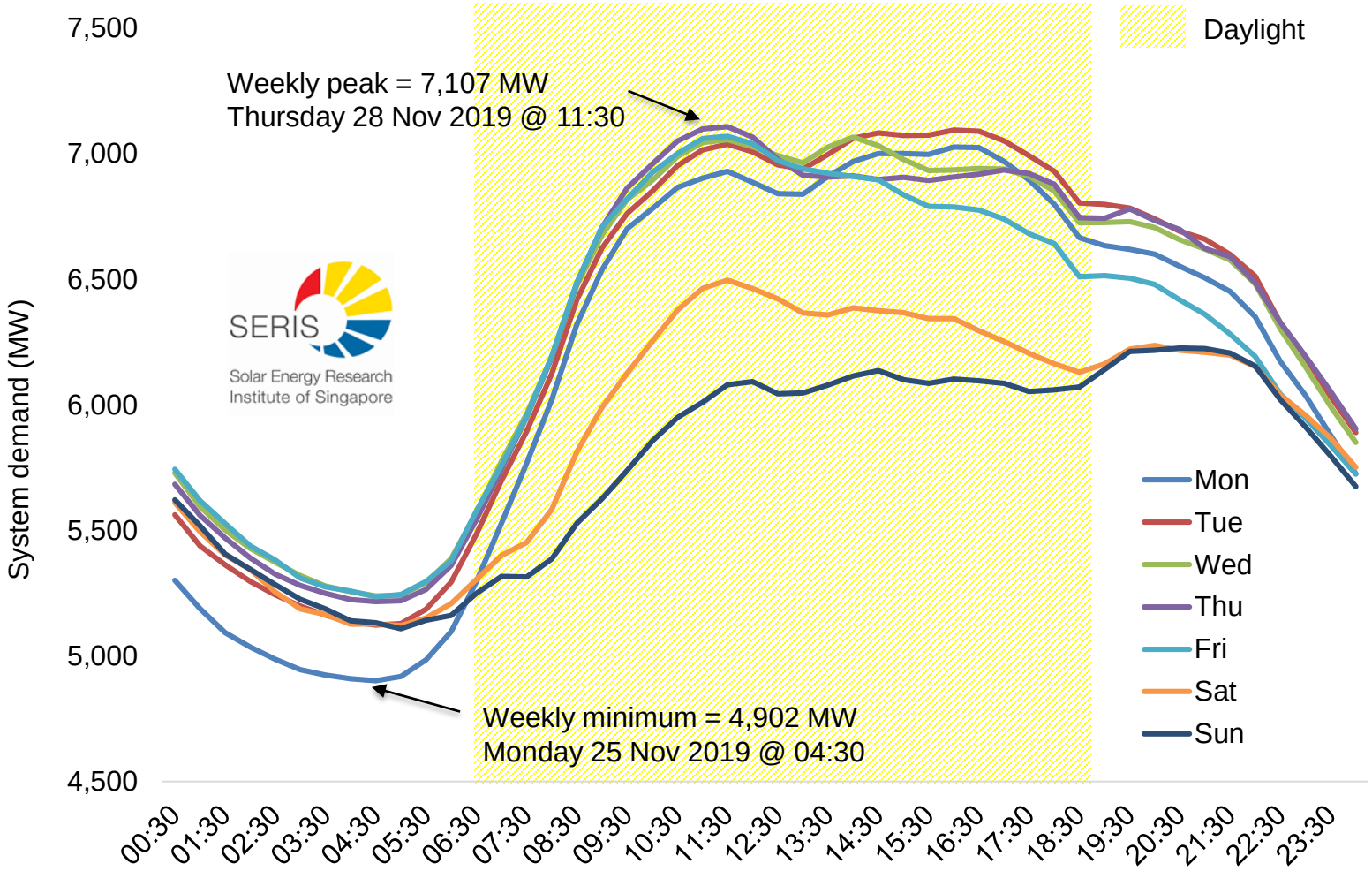
Electricity demand drivers



Data source: EMA, Singapore Department of Statistics, Ministry of Trade and Industry (GDP growth based on GDP in chained (2015) dollars)

Daily system peak demand profile

Example: Week from 25 Nov to 1 Dec 2019



Data source: EMA

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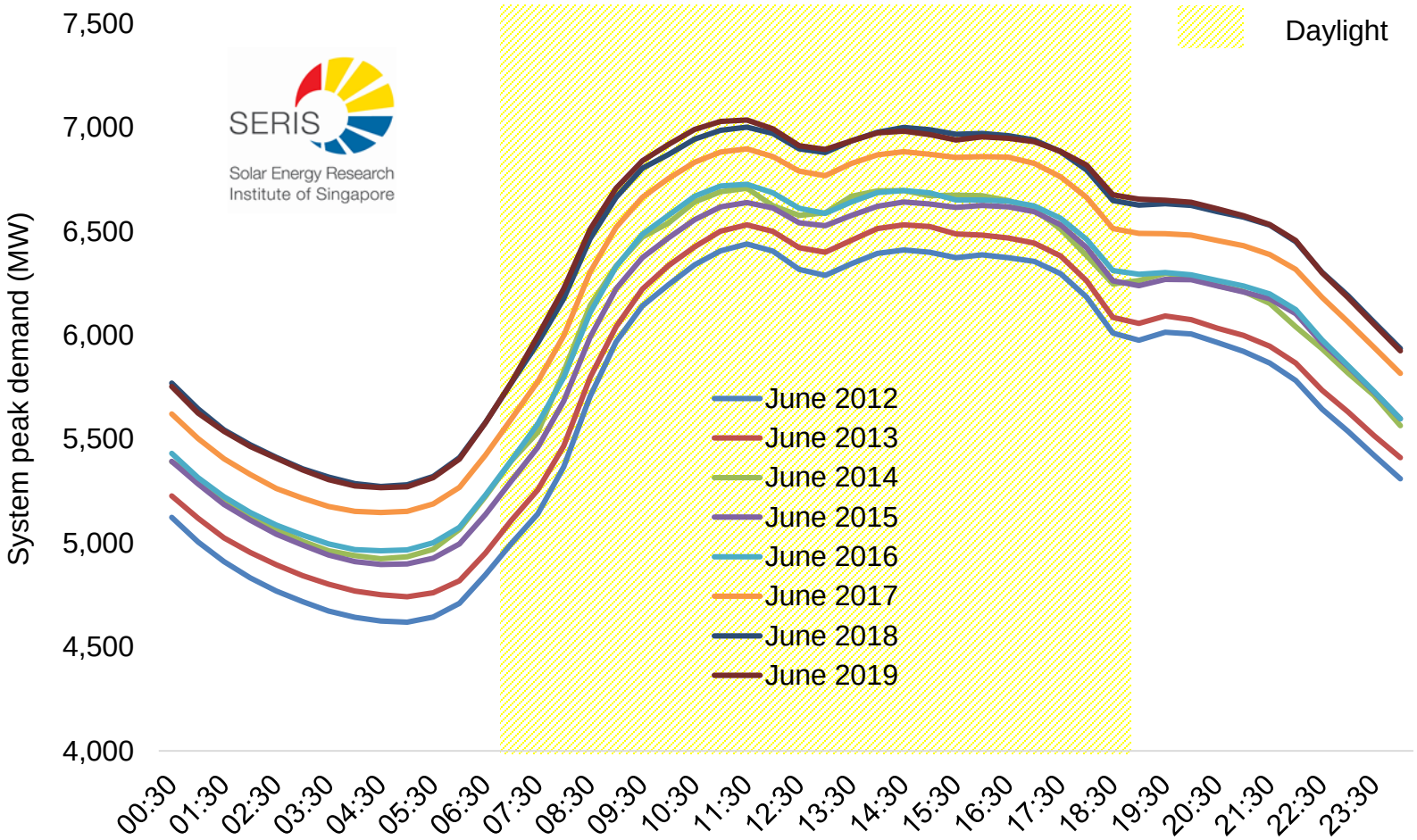
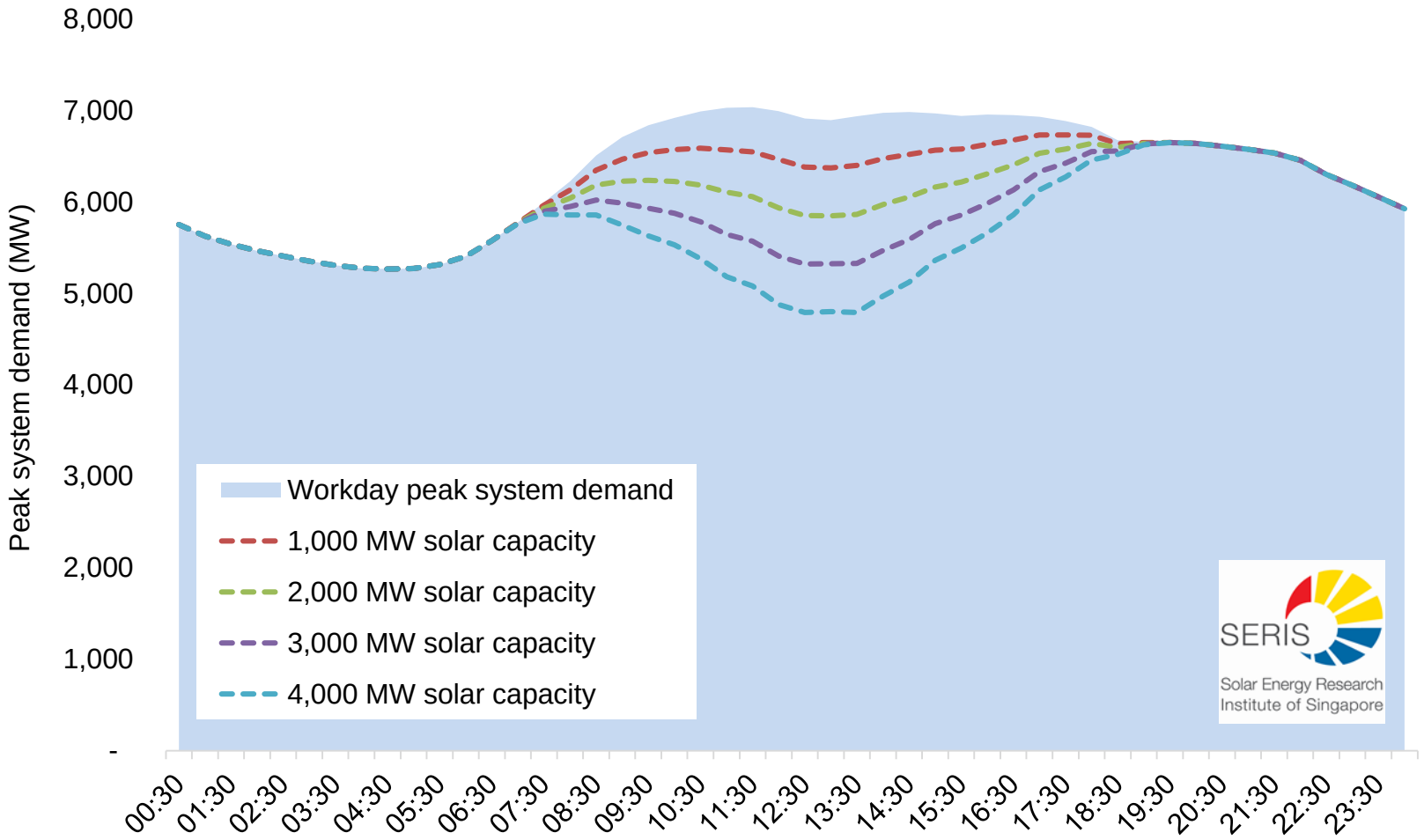
Historic system peak demand profile

No significant change of daily demand pattern over past eight years



Data source: EMA. Average daily profile for the month of June, excludes weekends/public holidays, the annual peak happened in different months for 2012 (May), 2016 (August) and 2019 (May)

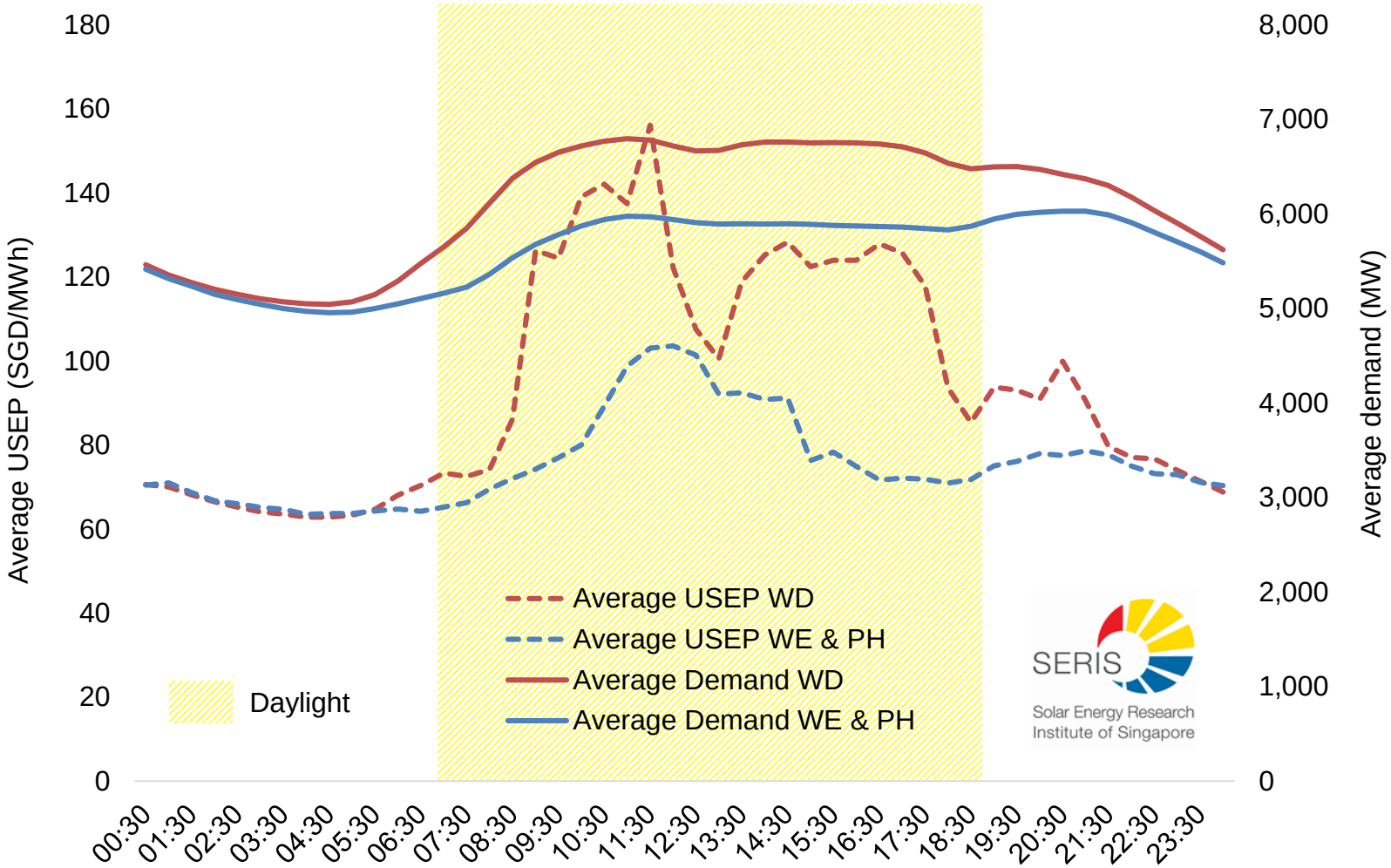
Peak-shaving potential of solar



Data source: EMA for average workday peak system demand (June 2019), mean GHI data aggregated over SERIS 25 weather stations (June 2019). Does not include temperature losses

Monthly USEP and demand curve

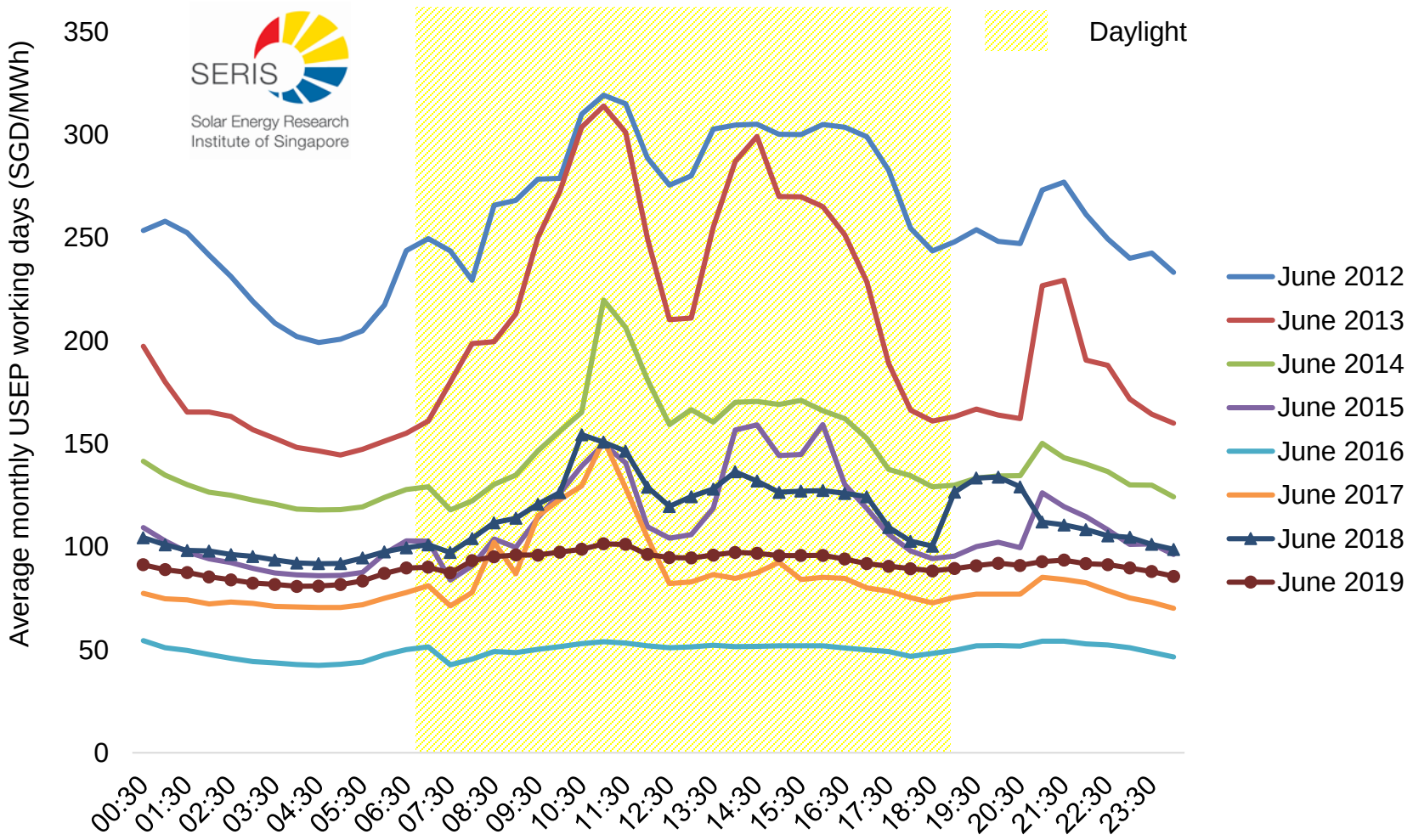
Example: November 2019



Data source: EMC. WD = working days, WE = weekends, PH = public holidays

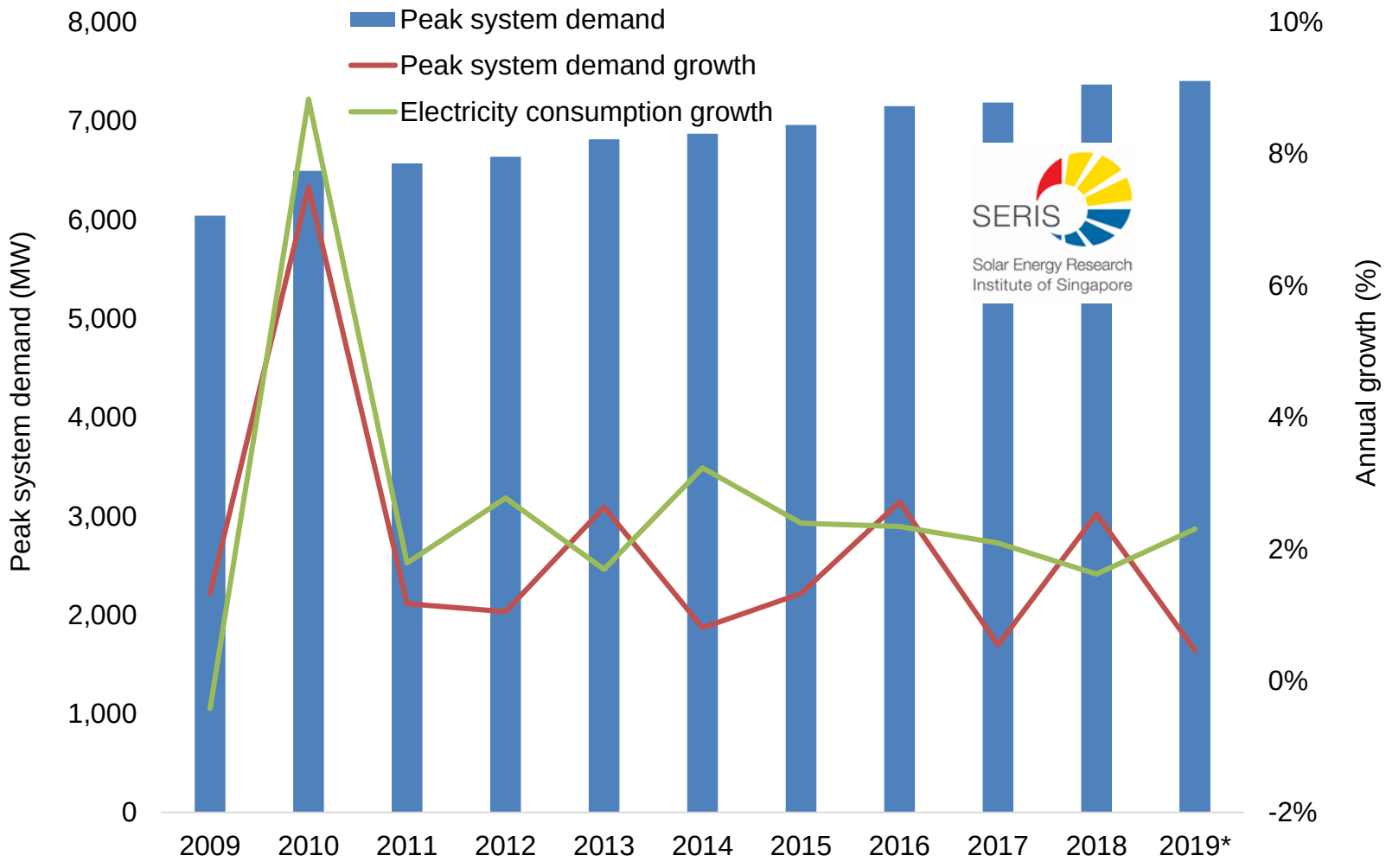
Historic USEP workday peak

June 2019 lower than June 2018



Data source: EMC. USEP of weekends and public holidays excluded

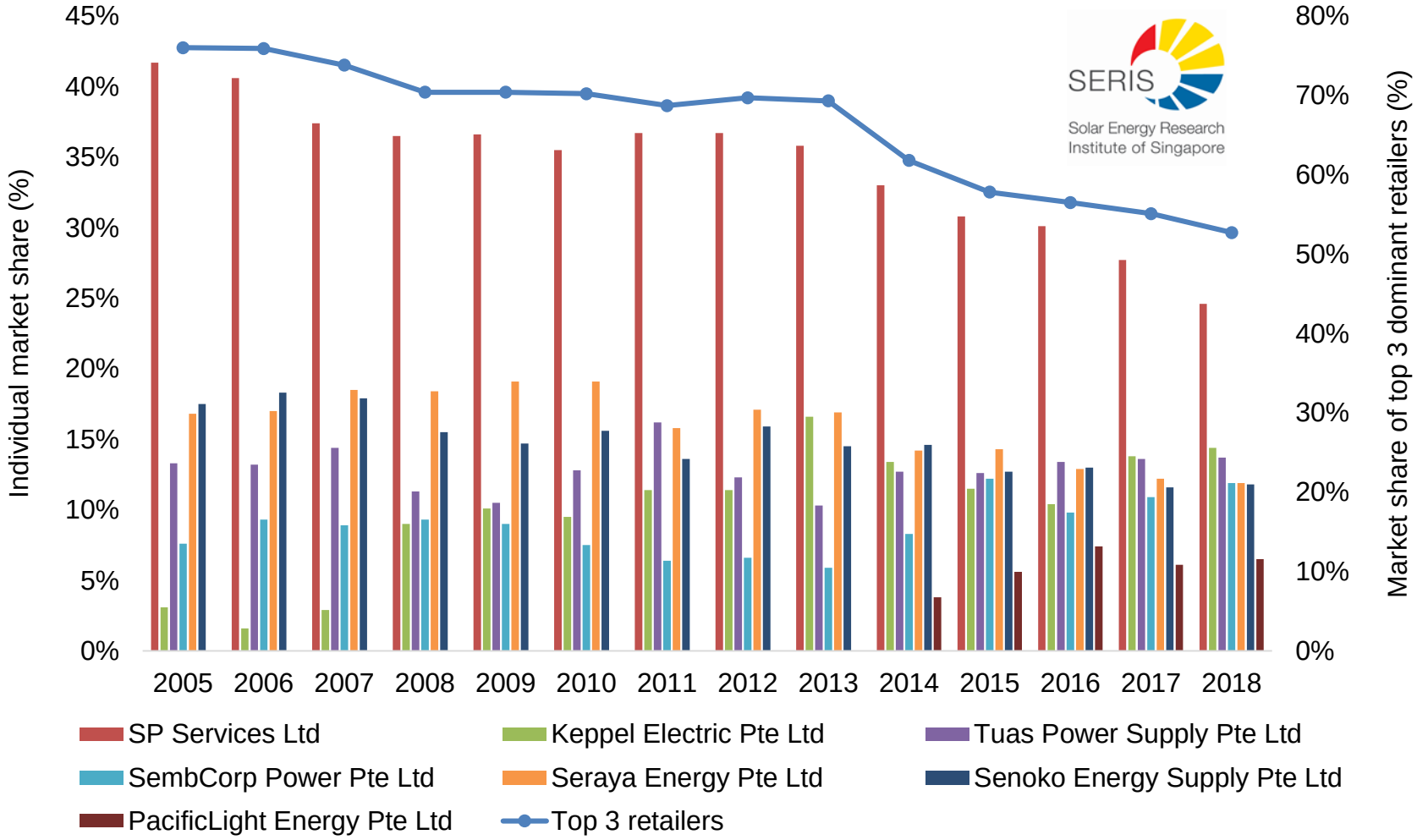
System peak demand



Data source: EMA. *2019 uses the peak which occurred in the month of May at 7,404 MW and 2019 electricity consumption growth estimated by using CAGR 2011-2018 = 2.3%

Development of market shares

Retail market is competitive: 20 active retailers by Dec 2019

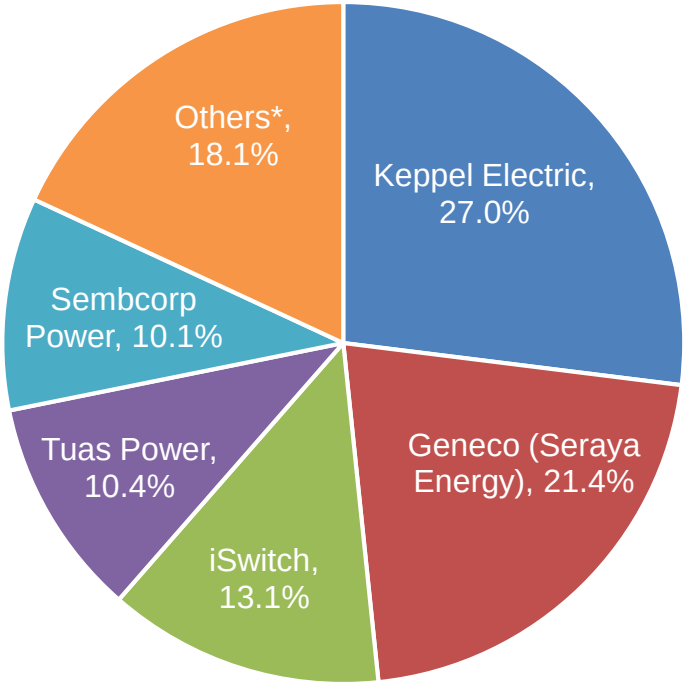


Data source: EMA, EMC

Residential vs. business retailers

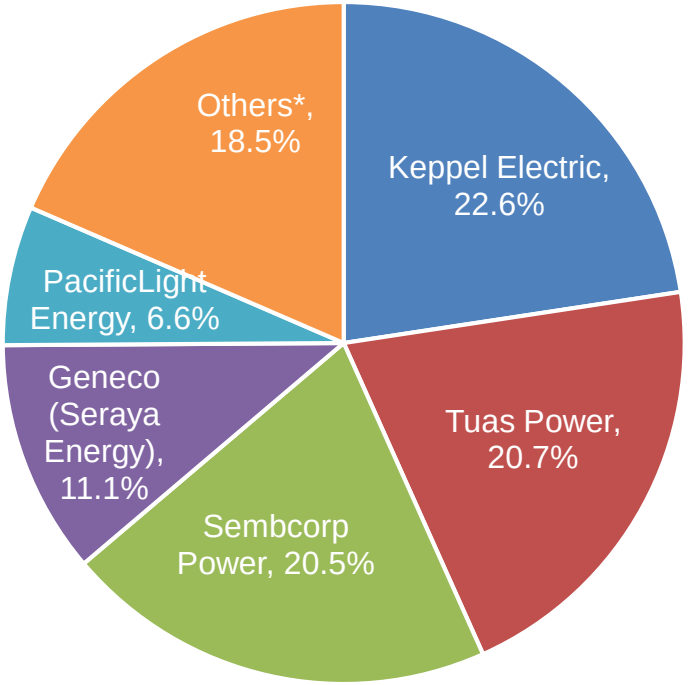
Market shares as of 31 August 2019

Residential



*Others = Best Electricity, Diamond Electric, PacificLight Energy, Ohm Energy, Senoko Energy, Sunseap Energy and Union Power

Business

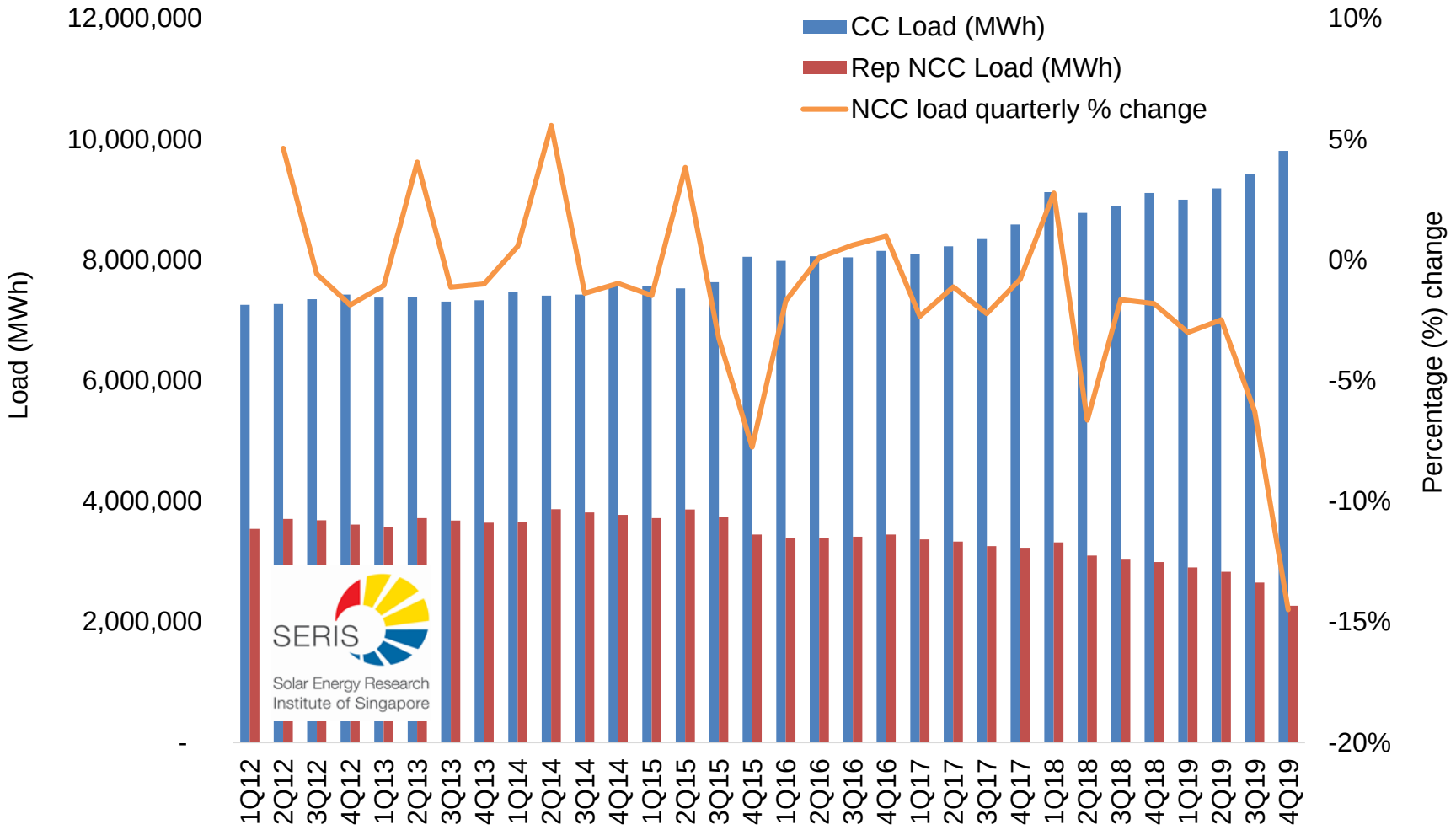


*Others = Best Electricity, Diamond Electric, Greencity Energy, Hyflux Energy, iSwitch, Just Electric, LHN Energy Resources, MyElectricity, Ohm Energy, Senoko Energy, Silvercloud Energy, Sun Electric, Sunseap Energy, UGS Energy, Union Power and ValuEnergy

Data source: EMA

CC vs. NCC load

Full retail liberalisation completed in May 2019



Data source: EMA. CC = contestable customers, NCC = non-contestable customers

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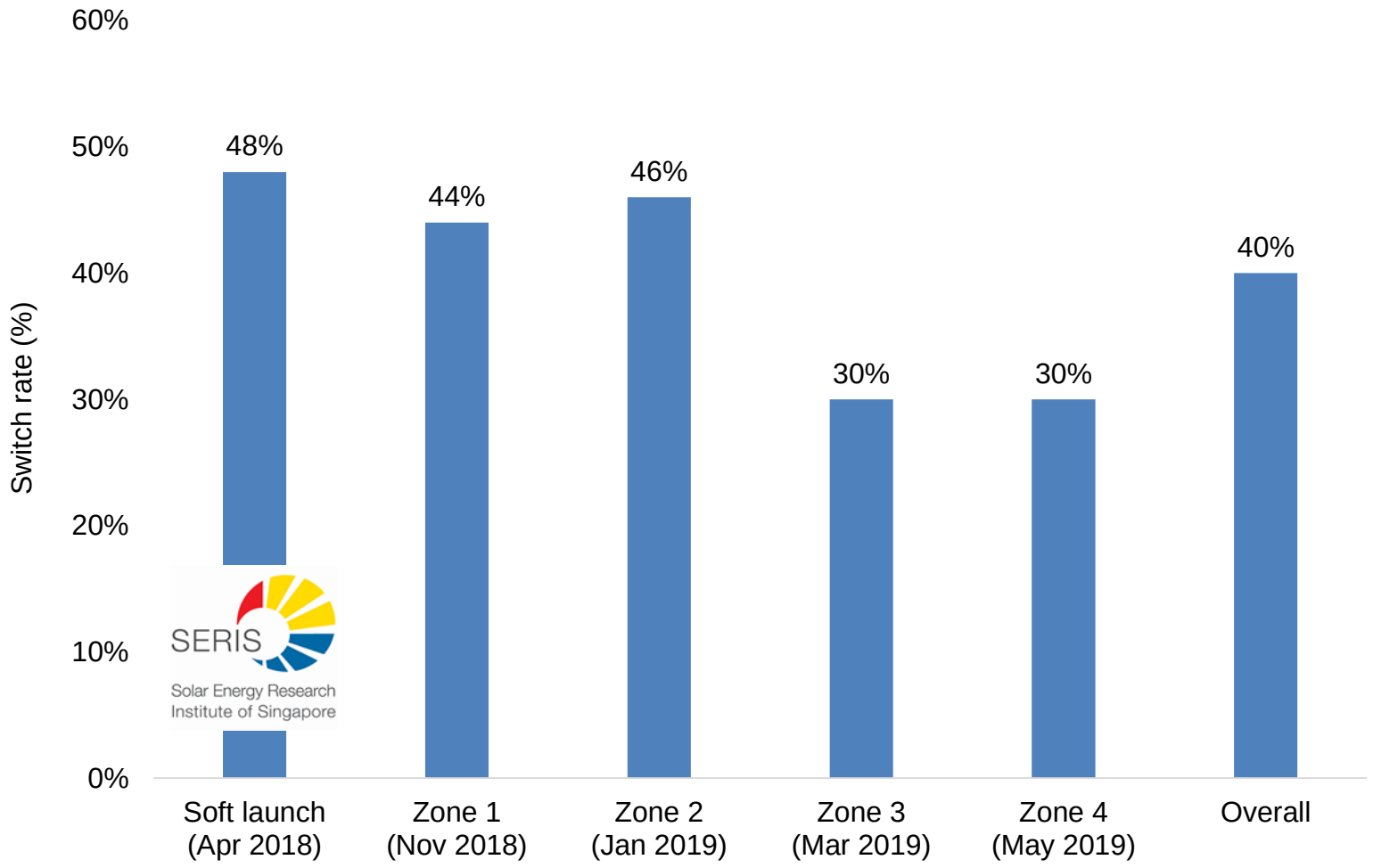
Switch rate of NCC load to retailers

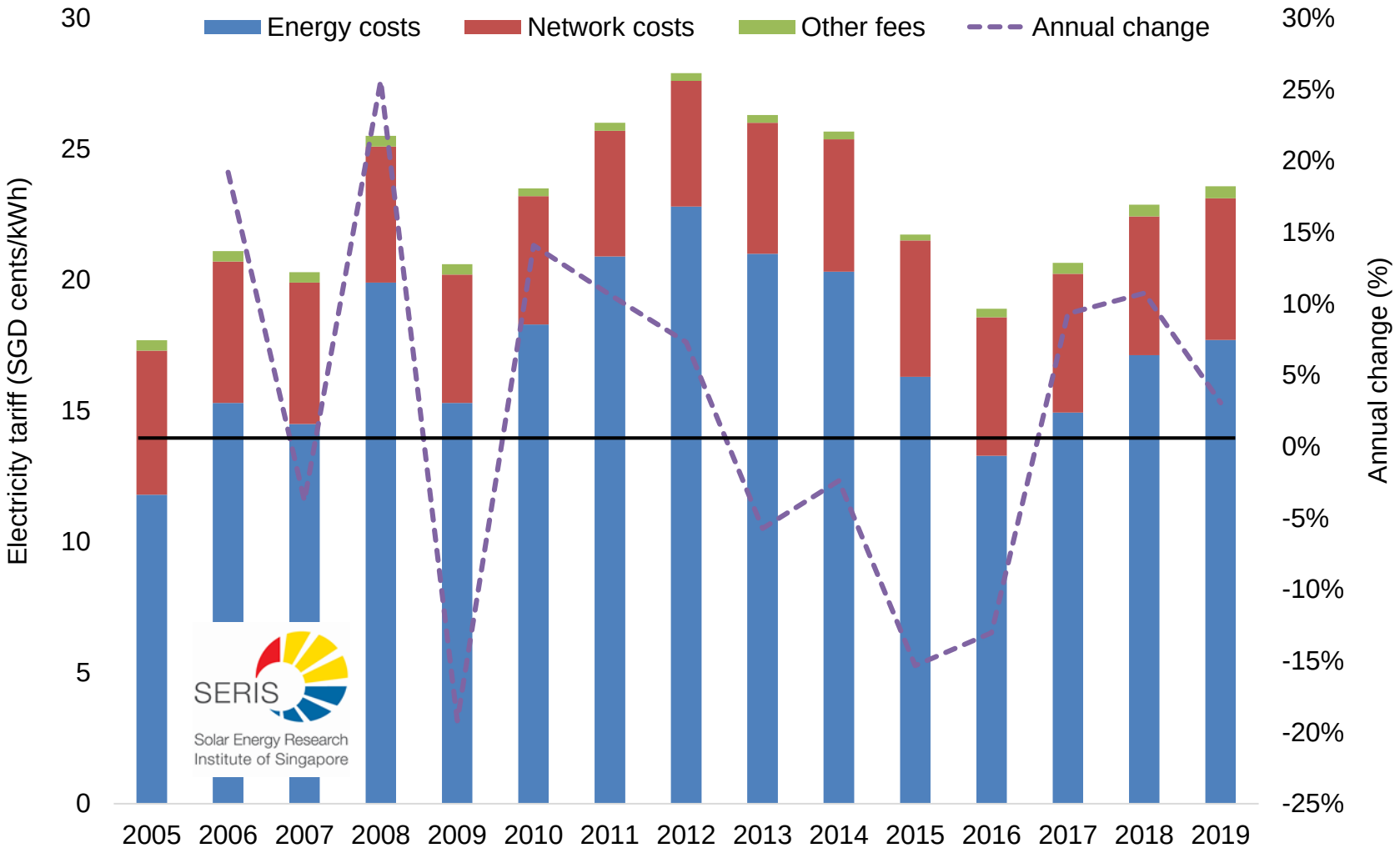
As of 31 August 2019



Data source: EMA. NCC = non-contestable customers

3d) Singapore electricity market: Prices

Electricity tariff (annual average)



Data source: EMA, SP Services. 2019 quarterly tariffs: 1Q = 23.9, 2Q = 22.8, 3Q = 24.2, 4Q = 23.4

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Vesting contracts

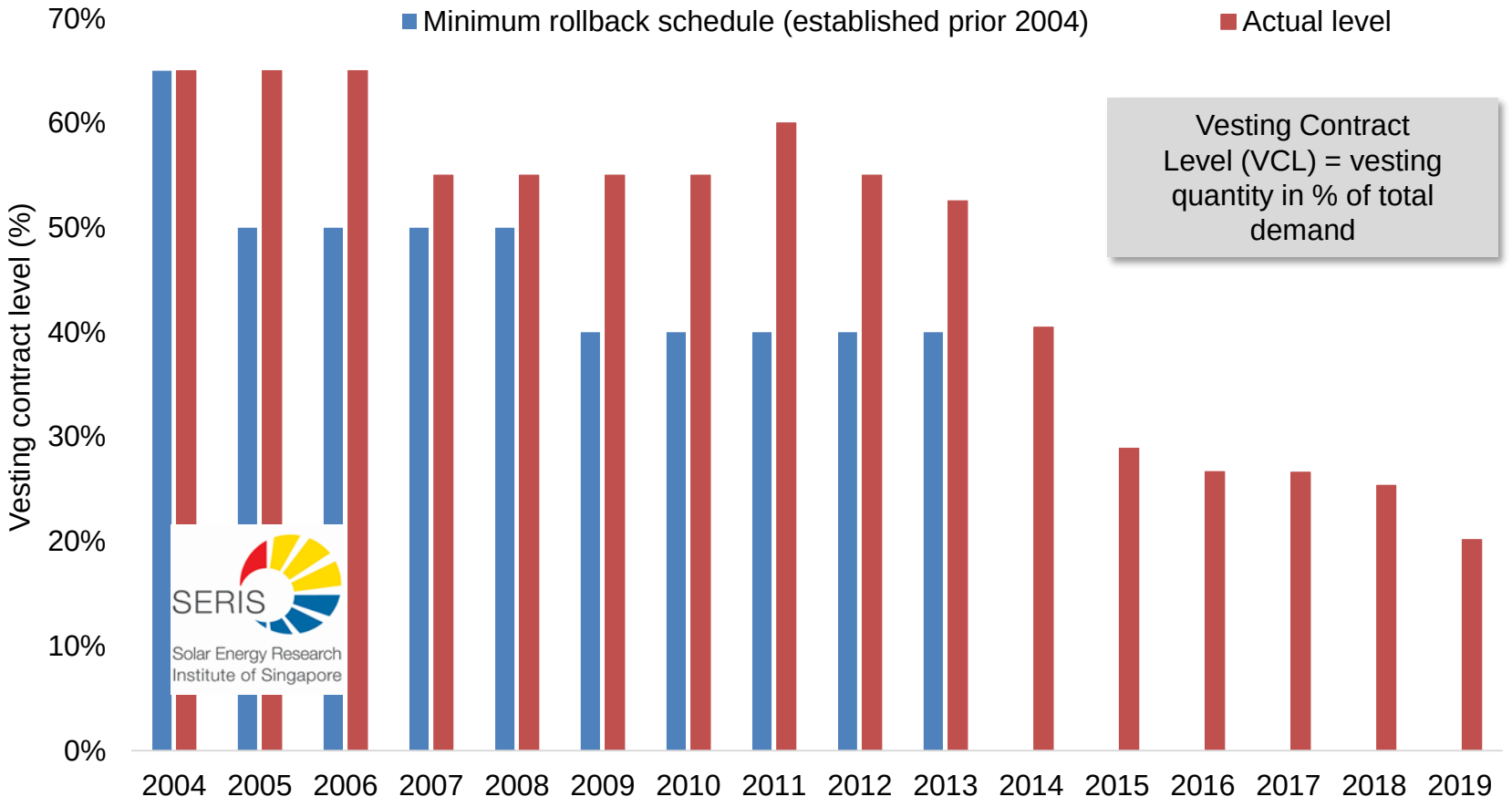
A unique feature of the Singaporean power market

- Implemented in Jan-2004 as a regulatory instrument to mitigate market power by the generation companies (gencos)*
- Commits gencos to sell a specified quantity (i.e. the Vesting Contract Level, VCL) for a specified price (i.e. the Vesting Price, VP)
- A 10-year LNG vesting scheme was introduced in May-13 to encourage the uptake of regasified LNG whereas eligible gencos receive the LNG vesting price for a specified LNG vesting quantity
- Vesting prices (one for piped gas and one for regasified LNG gas) are based on a regulatory review done every 24 months and are updated quarterly based on fuel cost and cost inflation changes
- Vesting prices mirror the long run marginal cost (LRMC, i.e. variable and fixed operating cost including reasonable return to investors) of the most efficiency power plant in Singapore (currently combined cycle gas turbines, CCGTs)

*Mandatory for Senoko Energy, PowerSeraya, Tuas Power, SembCorp, Keppel and PacificLight
Data source: EMA

Vesting contract level development

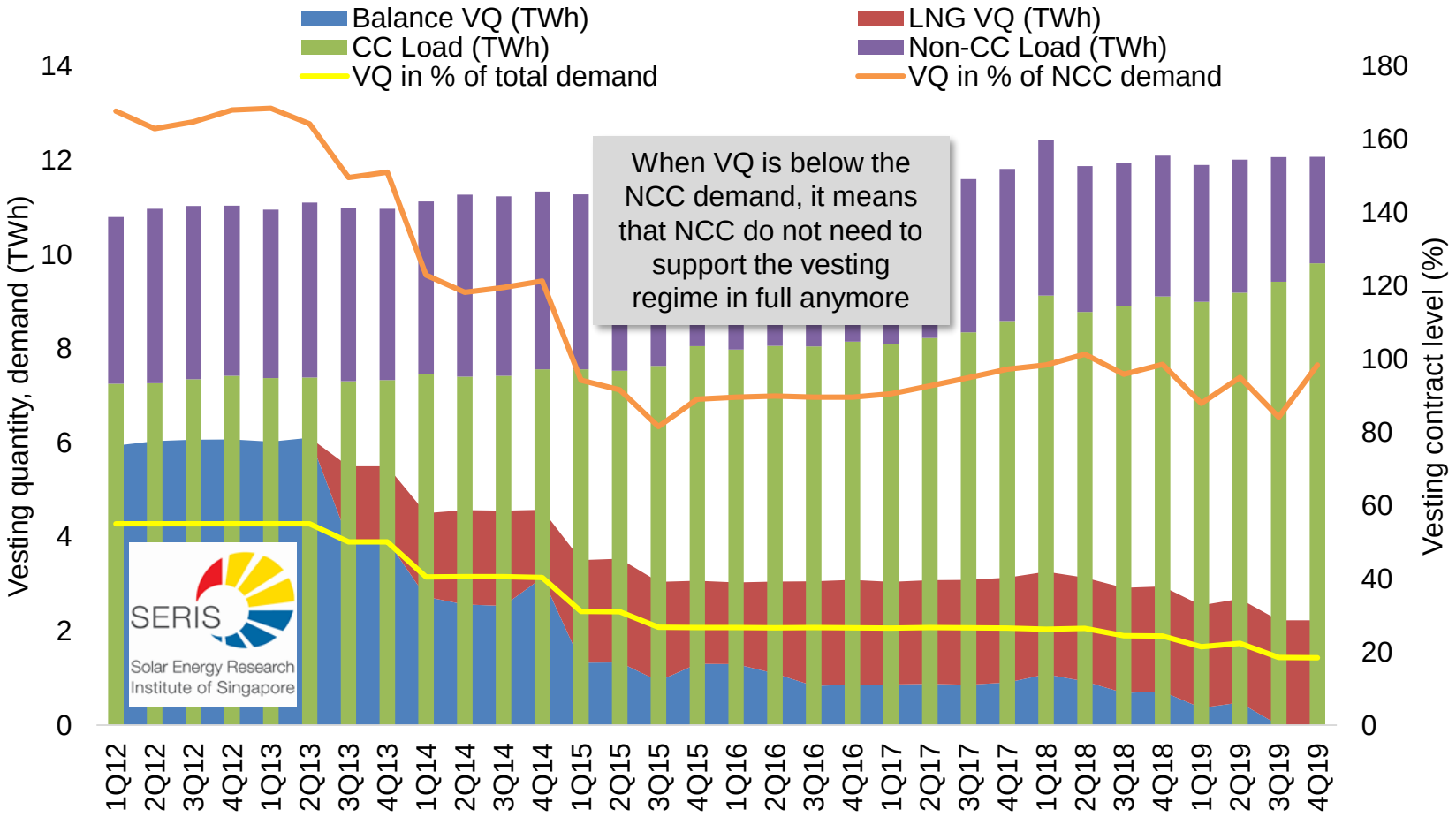
Declining impact from the vesting regime



Data source: EMA, SP Services. In a reaction of an appeal against EMA's Sep-14 determination of reducing the VCL to LNG vesting of ~18% by 2016, a more gradual reduction of the VCL to LNG vesting has been determined (25% until Jun-18, 22.5% until Dec-18, 20% until Jun-19, ~18% thereafter)

Quarterly vesting quantities (VQ)

The cost of the vesting regime is first passed-through to non-contestable clients (NCC*) with anything above to contestable clients (CC)



Data source: SP Services. *NCC are mainly residential or small commercial customers

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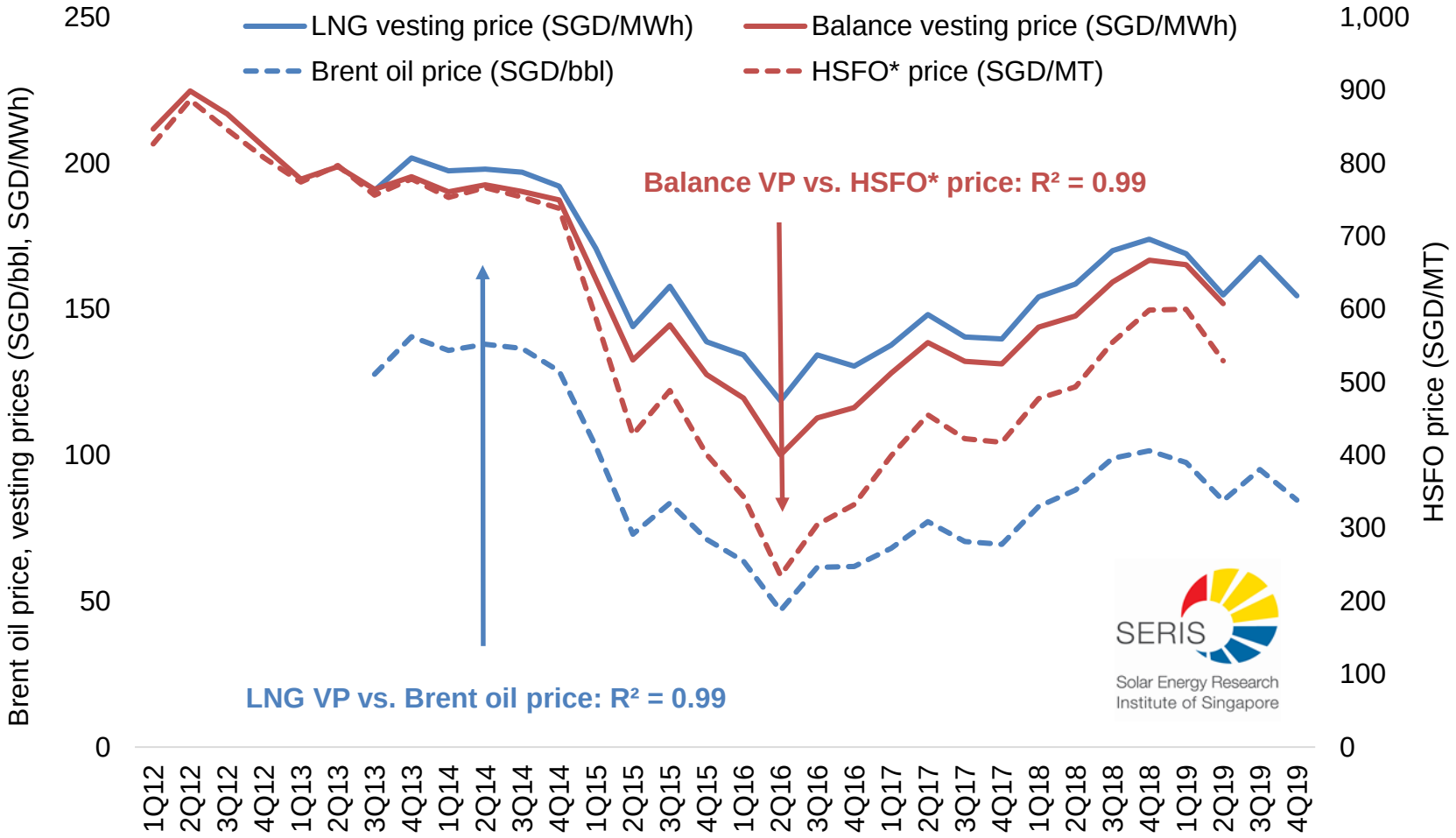
Quarterly vesting prices

High correlation with underlying fuel cost benchmarks



Data source: SP Services. *HSFO = High-Sulfur Fuel Oil

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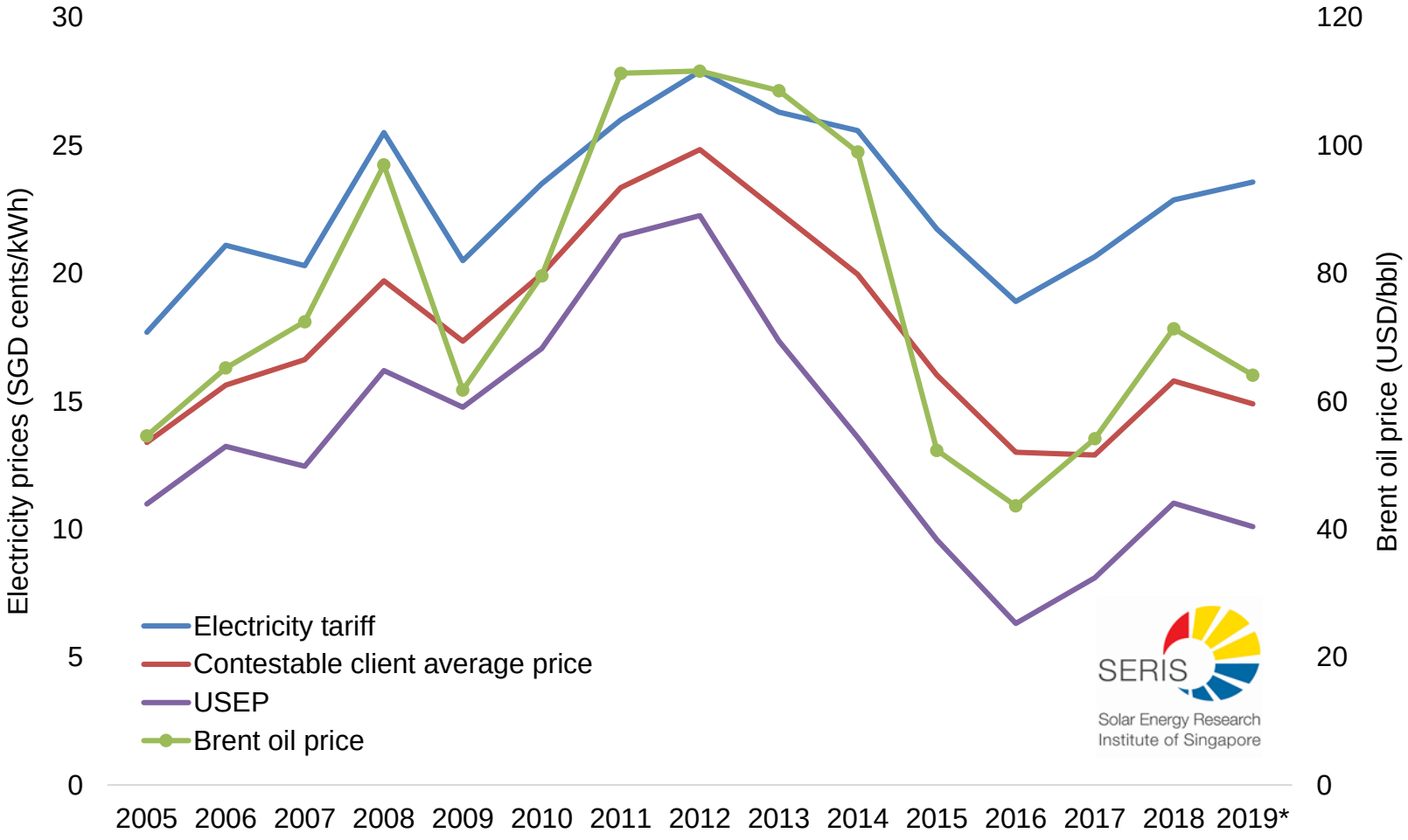
Brent oil price dependency

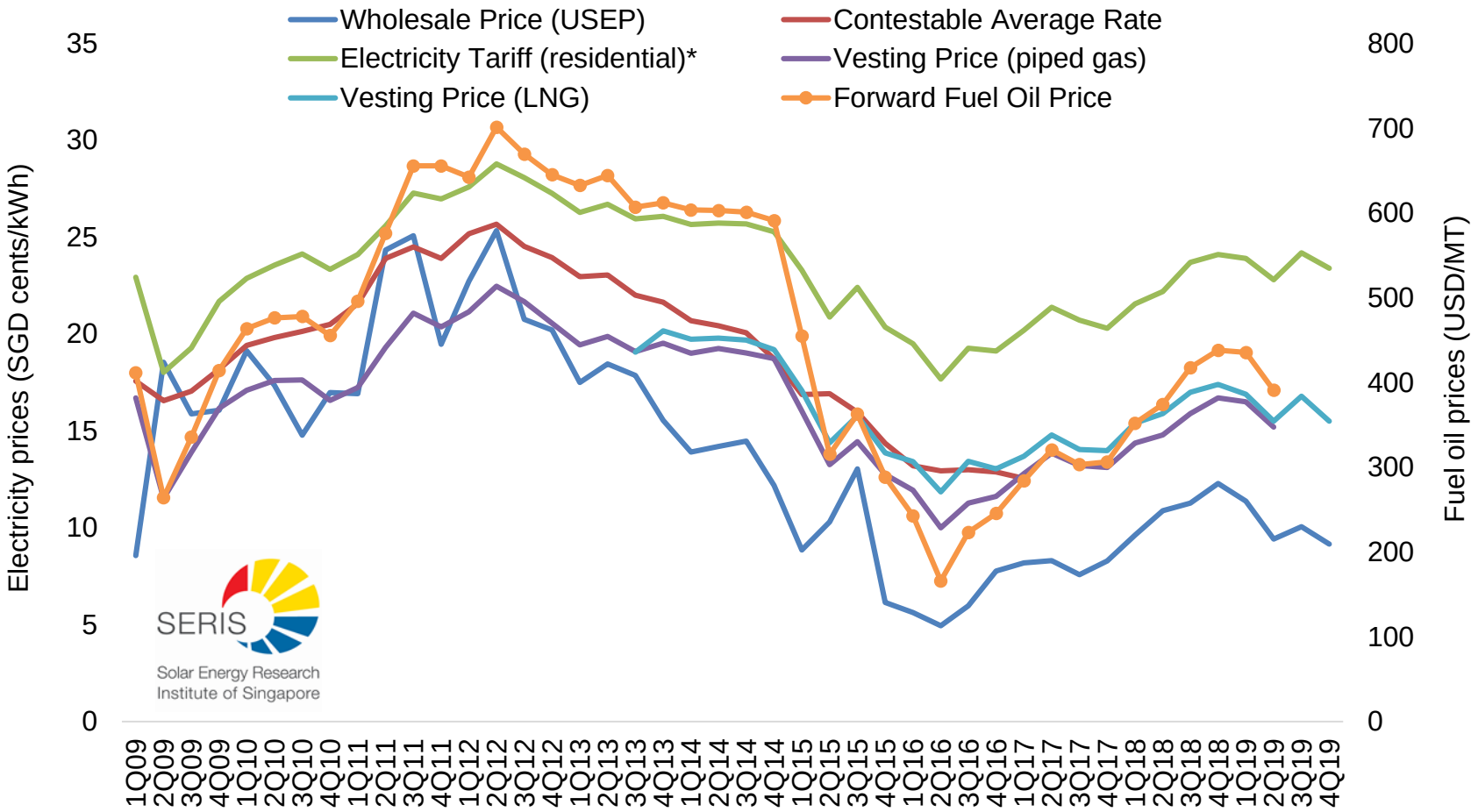
Also inherited in end-consumer electricity prices



Data source: EMA, SP Services, EIA. *2019 year-to-date until 30-Nov-2019 for oil price and USEP

Quarterly electricity prices

Also show a positive correlation to fuel oil prices (i.e. HSFO benchmark)



Data source: EMA, SP Services, EMC. Contestable average rate only available until Feb-2017, 4Q19 USEP including Oct/Nov 2019, *mainly residential and small commercial customers

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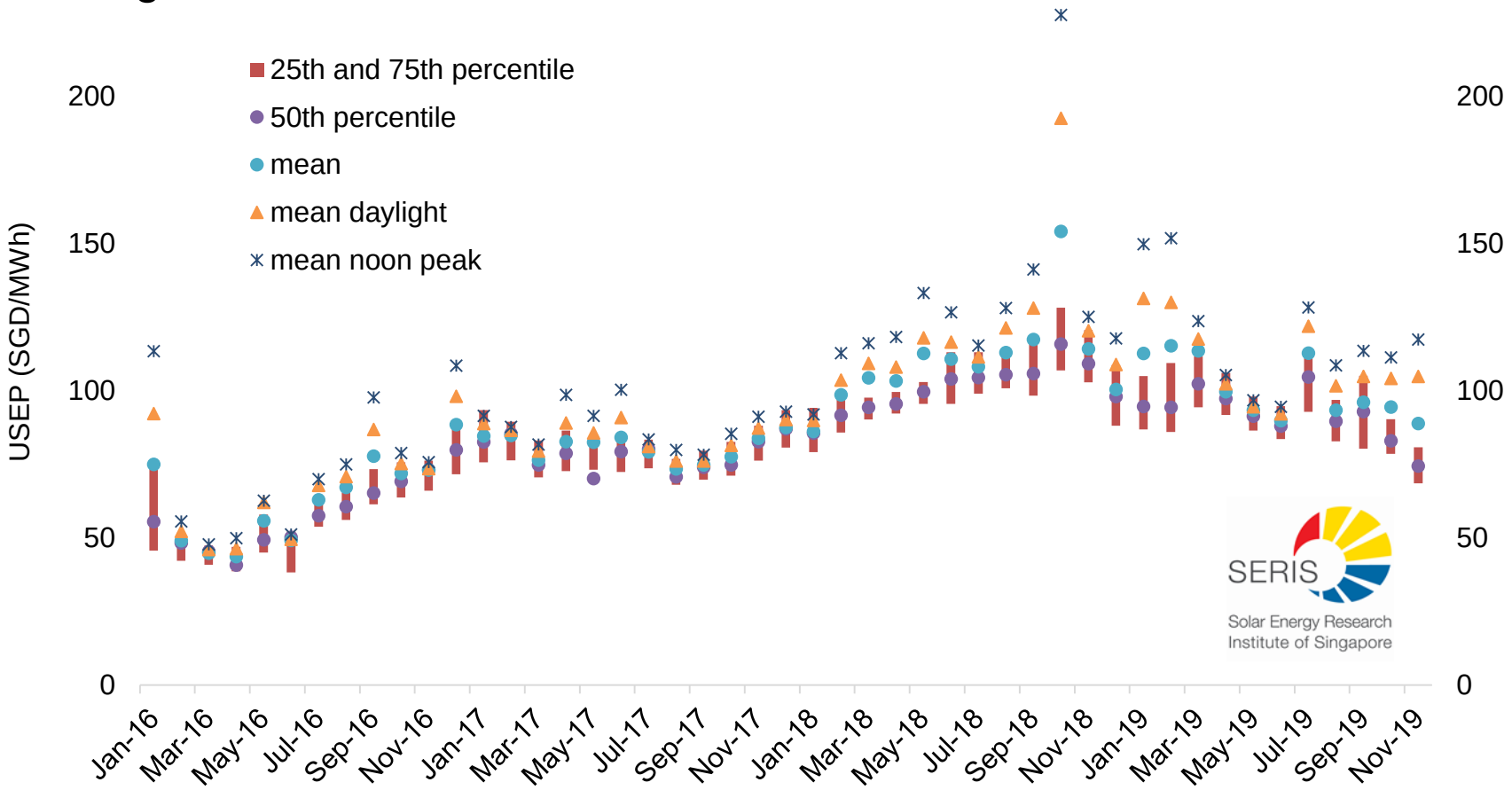
Wholesale power price statistics

Daylight[1)] and noon peak[2)] prices are ~7% and ~15% higher than averages



Data source: EMC. 1) Daylight is defined from 7:00 am to 7:00 pm, 2) noon peak is defined from 10:30 am to 2:30 pm

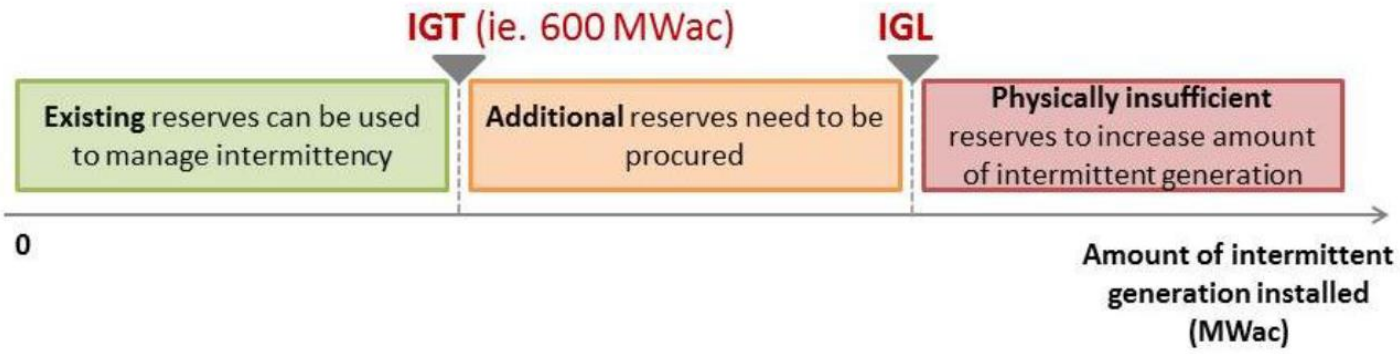
4. PV adoption in Singapore

EMA: regulatory enhancements

- Streamlining deployment process
  - ✓ Grid connection process reduced from 27 to 7 days
  - ✓ Empowering LEWs to commission solar installations
  - ✓ Developing checklist / one-stop portal to facility information
  - ✓ Consumers with no intention to export with installations < 10 MWac have a streamlined registration procedure
  - ✓ Solar Generation Profile to reduce metering costs
- Simplifying payment procedure
  - ✓ Non-contestable consumers < 1 MWac can receive payment through a direct credit adjustment via SP Services (“Simplified Credit Scheme”)
  - ✓ Contestable consumers < 10 MWac can receive payment through SP Services, no need to register directly (“Enhanced Central Intermediary scheme”)
  - ✓ “Net settlement” for everyone

EMA: managing variability

- "Dynamic pathway approach" to allow the amount of reserves to grow in tandem with solar PV deployment
- Intermittent Generation Threshold (IGT) increased to 600 MWac from 350 MWac in October 2013



- Intermittency Pricing Mechanism (IPM): To allocate a fair share of reserve costs to all IGS installations except for residential solar installations and non-residential embedded solar installations connected to the grid on or before 31 January 2018. To be implemented around 2020

Source: EMA, July 2014 and October 2018, Final Determination Papers

EMA: Snapshot of requirements

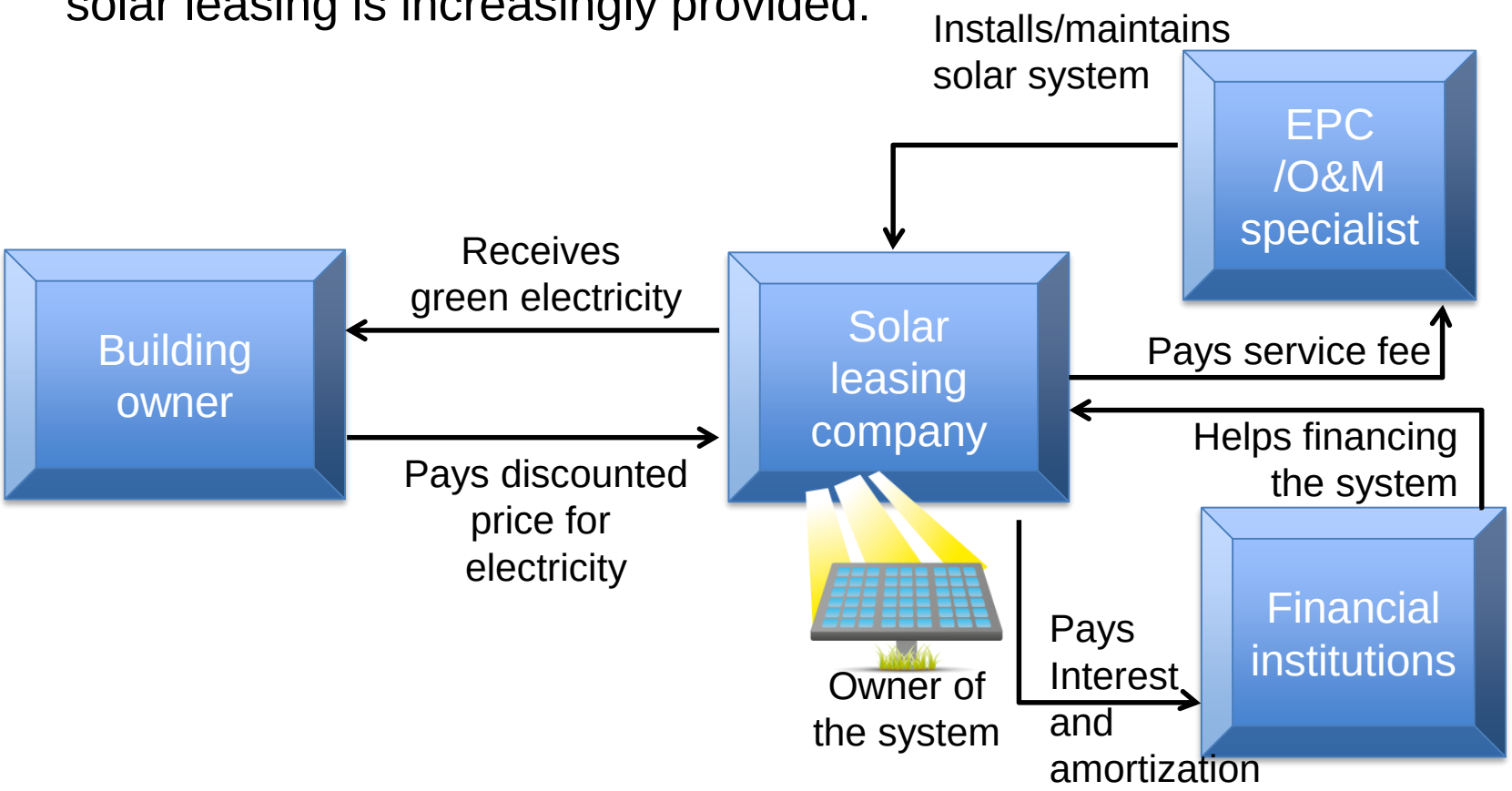
- Licensing with EMA: < 1MWac exempt, > 1MWac wholesaler (generation) license, > 10MWac generation license
- Registration with EMC:
  - option to register via SP Services
  - direct EMC registration required (if no export payment, streamlined)
  - < 10 MWac, Contestable: Enhanced Central Intermediary Scheme ("ECIS")
  - < 1 MWac, Non-Contestable: Simplified Credit Scheme ("SCS")
- Remuneration for export: nodal price, exceptions: SCS: energy component of grid tariff, ECIS: pool price (i.e. USEP[1)])
- Monitoring: > 1MWac real-time data submission requirement to PSO
- Metering: bi-directional revenue-class meters at generation and consumption side, exception: SCS: bi-directional meter at generation side sufficient, ECIS/no exports: choice of generation estimation[2)]

1) Uniform Singapore Energy Price, weighted-average of all nodal prices in each half hour, 2) charges based on EMA's Solar Generation Profile estimate

Innovative business models (1)

Solar PPA (in Singapore often called “Solar Leasing”)

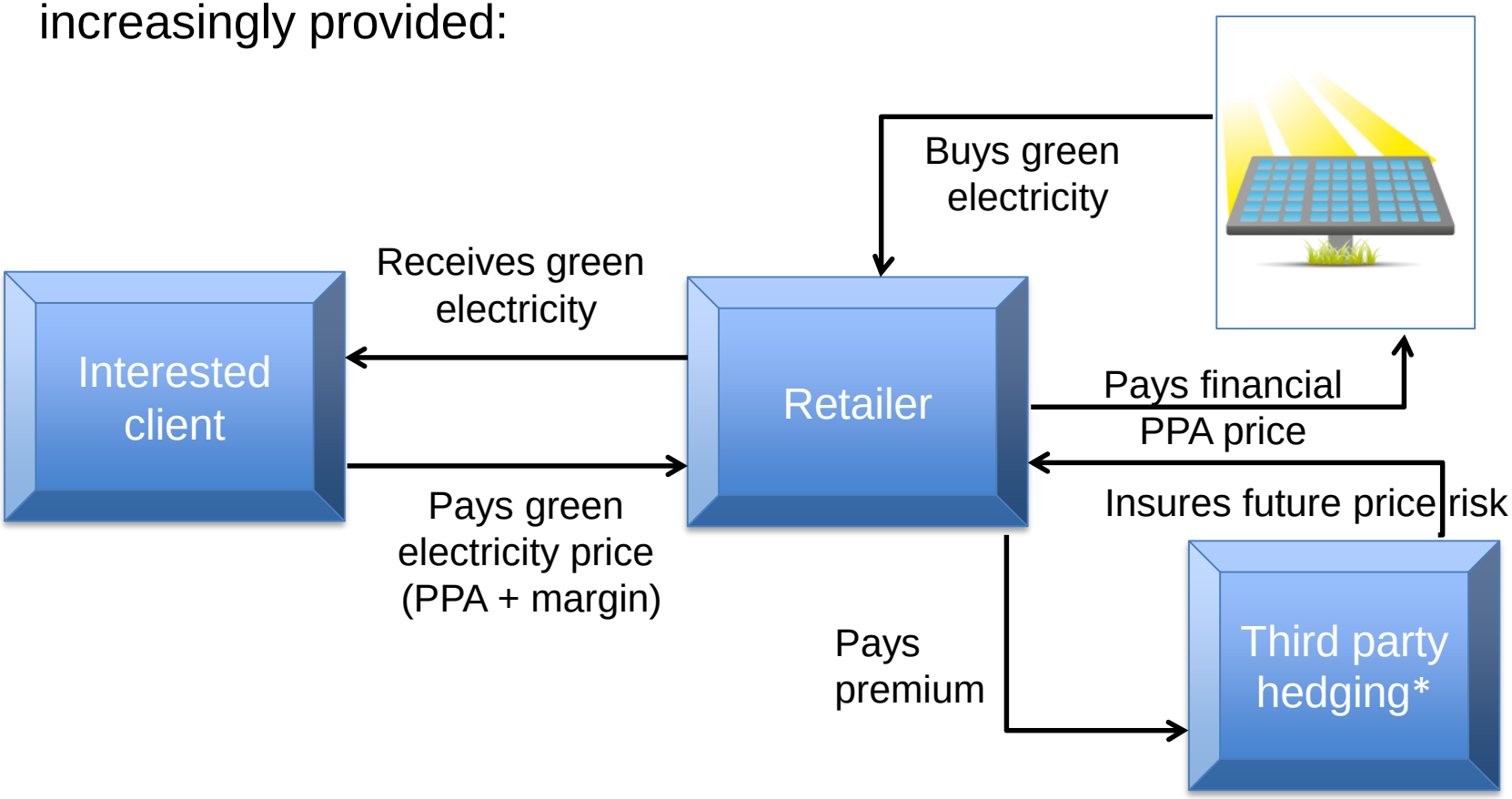
- Instead of owning and paying for the system directly, the option for solar leasing is increasingly provided:



Innovative business models (2)

Green electricity retailing

- Instead of owning a suitable roof, green electricity retail products are increasingly provided:

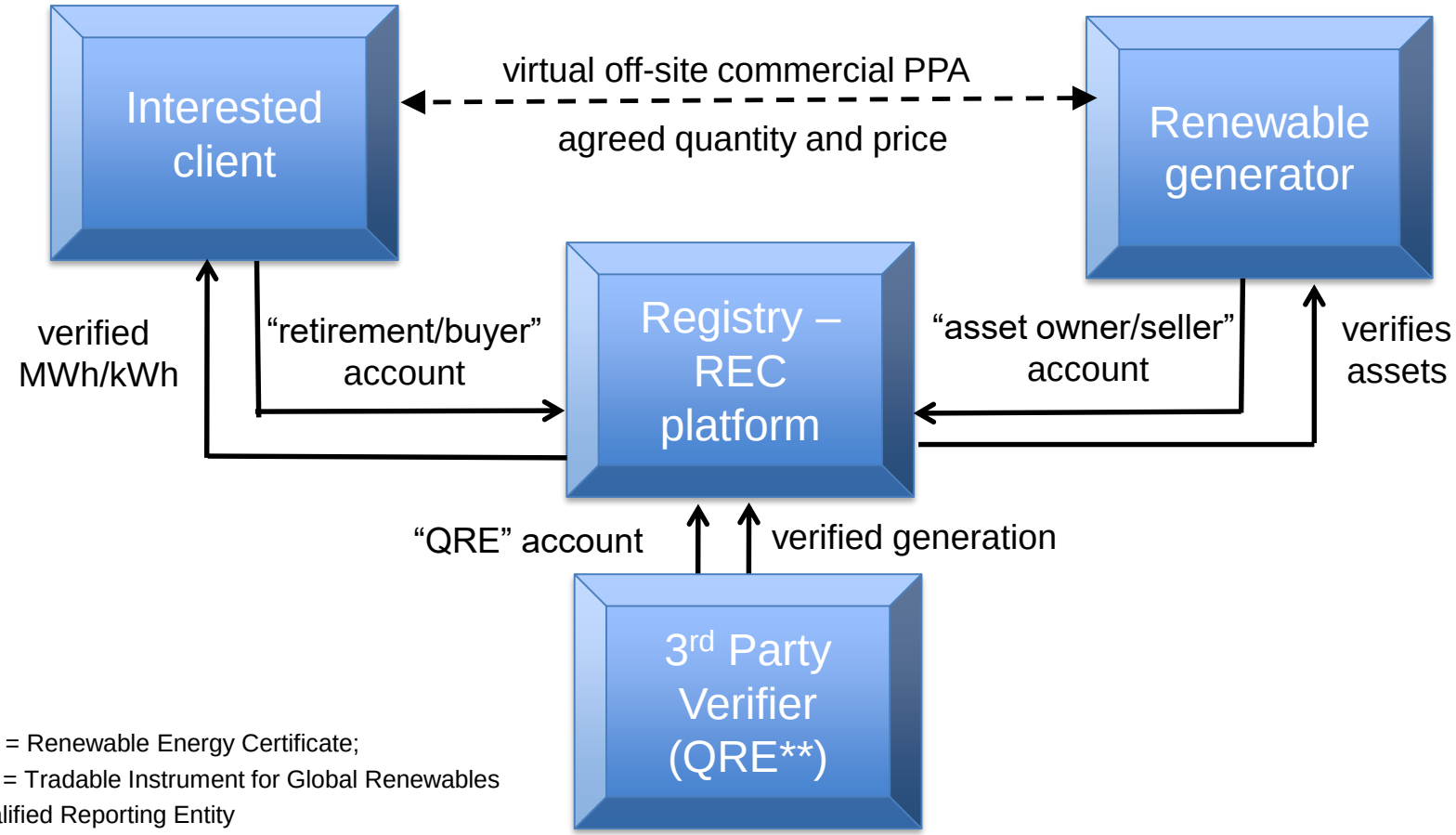


*as example through the Futures wholesale power market or with a generation company

Innovative business models (3)

Selling green attributes (REC, TIGR*)

- Central platform run by third party (e.g. APX, SP Group, etc.) where each unit of MWh or kWh produced green attributes are tracked via individual serial numbers until retirement



*REC = Renewable Energy Certificate;
TIGR = Tradable Instrument for Global Renewables
**Qualified Reporting Entity

Levelised Cost of Energy (LCOE)

Up-front investment + O&M + Insurance + Loan Payment +/- Tax +/- Residual value






$$\text{LCOE}^* = \frac{\text{Total life cycle cost}}{\text{Total lifetime energy production}}$$




Irradiance (kWh/m2) x Performance Ratio (%) = Initial energy yield (kWh/kWp) - Annual degradation rate

* Calculated as a net present value figure: all input factors are annually discounted by the project hurdle rate (e.g. average weighted cost of capital)

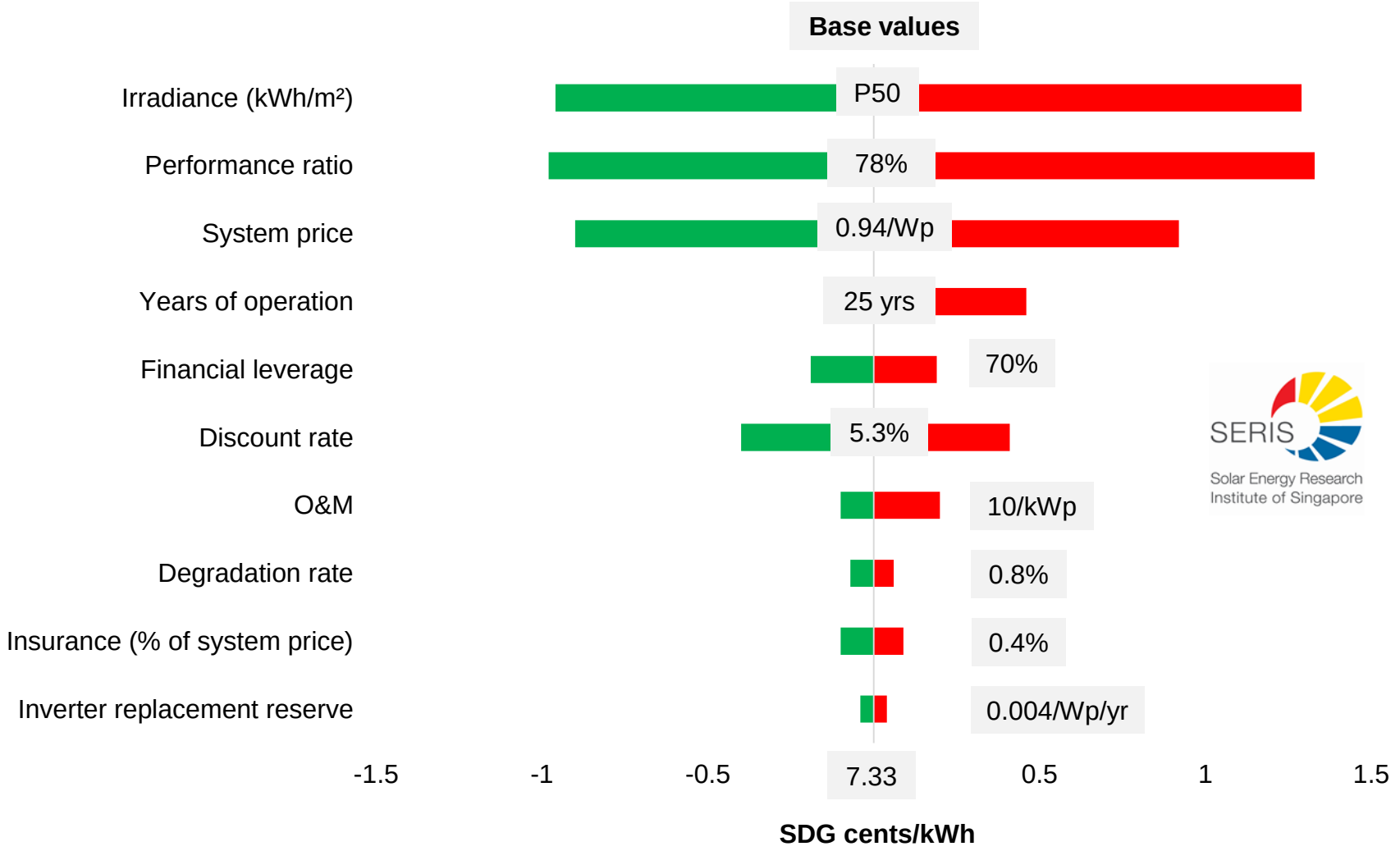
Example: 1MW$_p$ industrial roof

- System size: 1 MWp, System price: ~940 SGD/kW$_p$
- Total capex: SGD ~0.94 million (of which equity ~0.28 million)
- Total lifecycle costs: SGD ~1.2 million
- 70% debt finance, 3% over risk-free rate, 7 years at 4.7%
- 8.5% equity cost, 17% tax rate, 5.3% discount rate
- 78% performance ratio, average irradiance of ~1,644 kWh/m^2 (P50)
- First year energy yield: ~1,282 kWh/kWp
- 0.8% degradation rate p.a., 25 years operational life
- 0.4% insurance cost p.a. (in % of total investment cost)
- Cost inflation 1.7% p.a.
- Annual operating and maintenance expense: 10 SGD/kW$_p$
- Inverter warranty extension cost at 25%, 45% and 60% of prevailing inverter price factored in every 5th year, respectively (increasing with the average age of the inverters)

LCOE = 7.33 SGD cents per kWh (pre-tax)

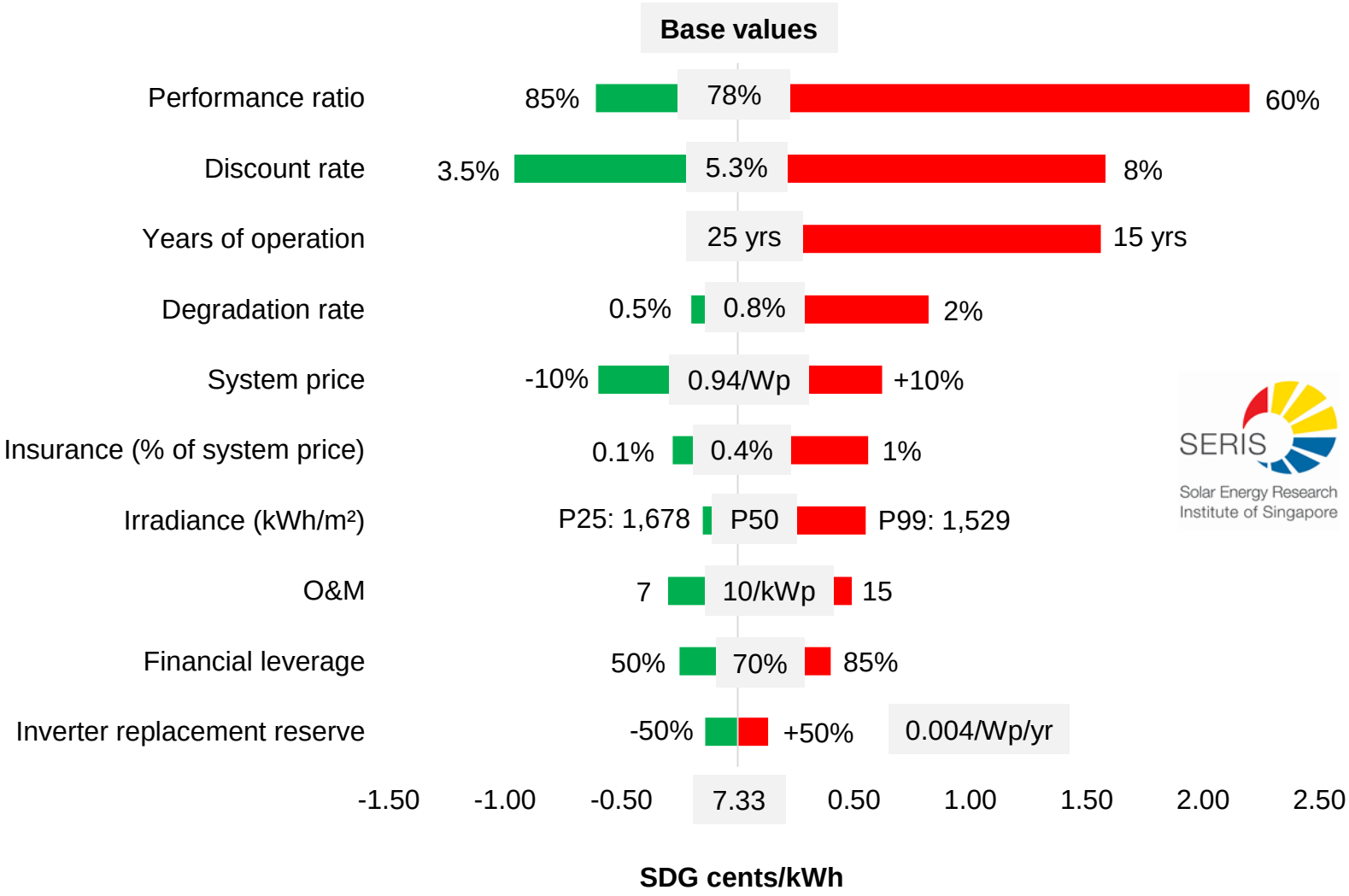
Sensitivity analysis (+/- 15%)

Most critical LCOE parameters are energy yield and system price



Sensitivity analysis (individual ranges)

Most critical LCOE parameters are performance ratio and discount rate



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Example: 10 kW_p residential roof

- System size: 10 kWp, System price: 1,540 SGD/kW_p
- Total investment: SGD ~15,400, no debt-financing considered
- Total lifecycle costs: SGD ~20,600
- 5.5% discount rate, depreciated over 25 years
- 78% performance ratio, average irradiance of ~1,644 kWh/m^2 (P50)
- 1st year energy yield/production: ~1,282 kWh/kWp, ~12.8 MWh
- 0.8% degradation rate p.a., 25 years of operational life
- 0.4% insurance cost p.a. (in % of total investment cost)
- Annual operating and maintenance expense: 19 SGD/kW_p
- Inverter warranty extension cost at 25%, 45% and 60% of prevailing inverter price factored in every 5th year, respectively (increasing with the average age of the inverters)

LCOE = 12.50 SGD cents per kWh (pre-tax)

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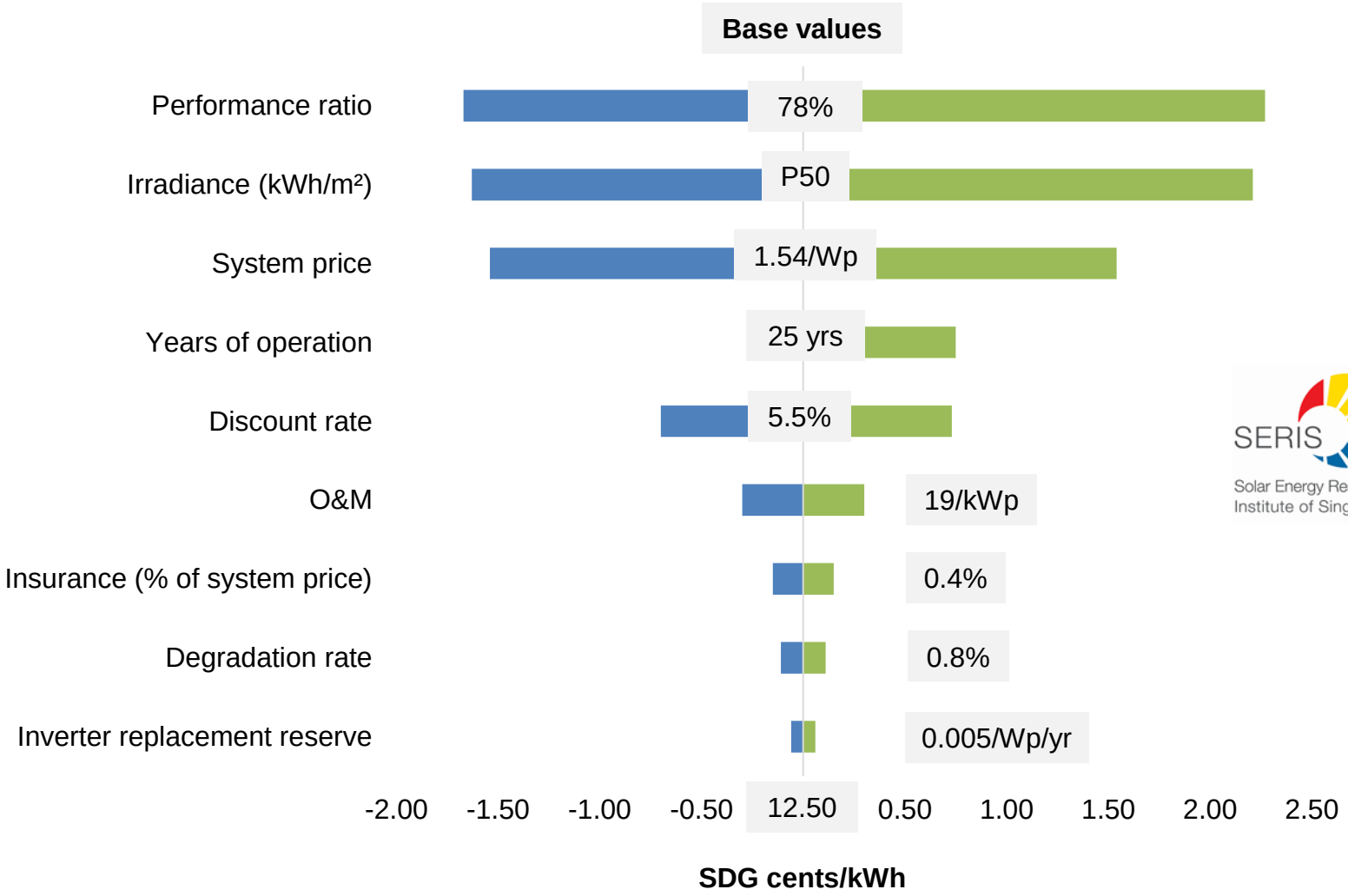
Sensitivity analysis (+/- 15%)

Most critical LCOE parameters are energy yield and system price



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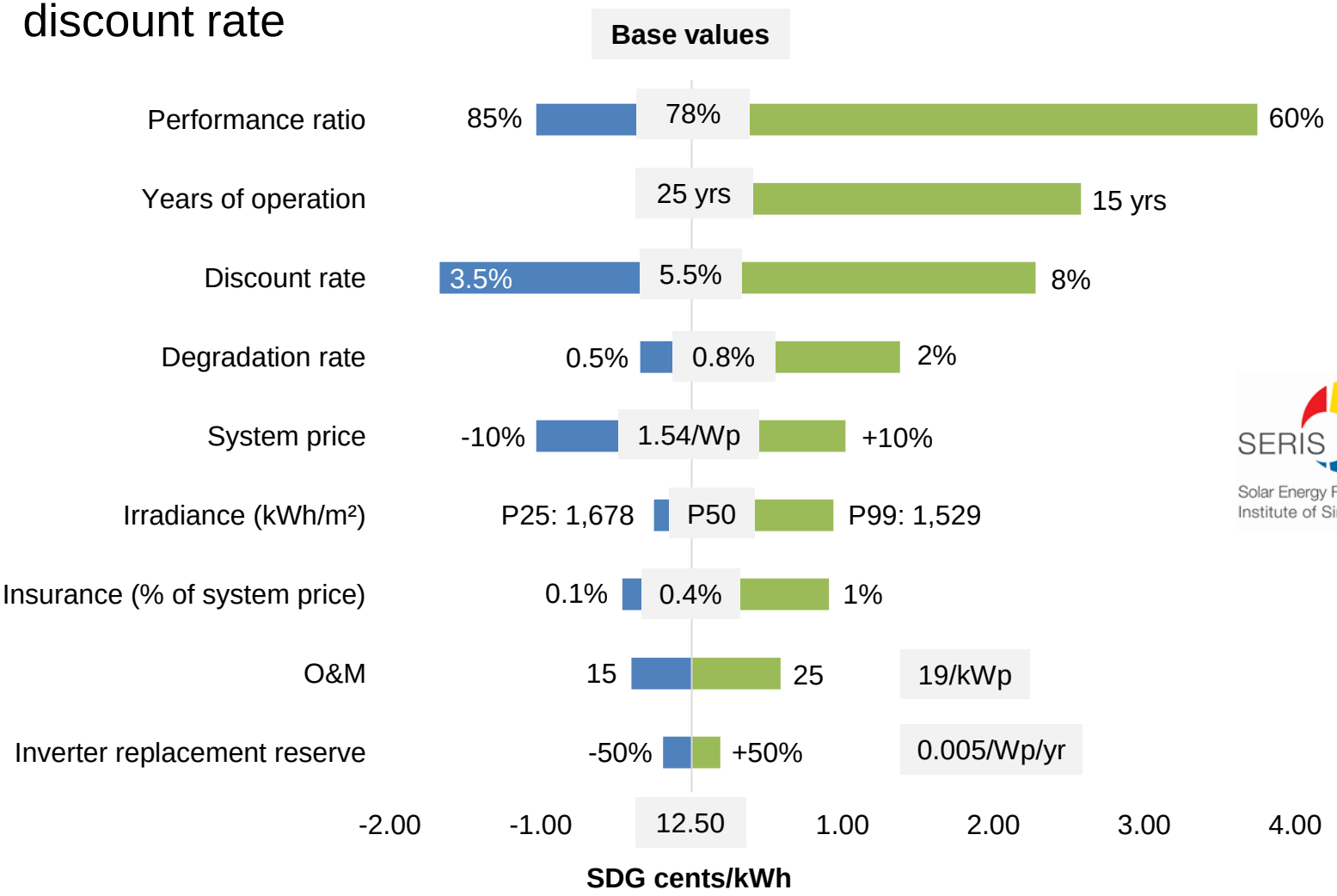
Sensitivity analysis (individual ranges)

Most critical LCOE parameters are performance ratio, durability and discount rate



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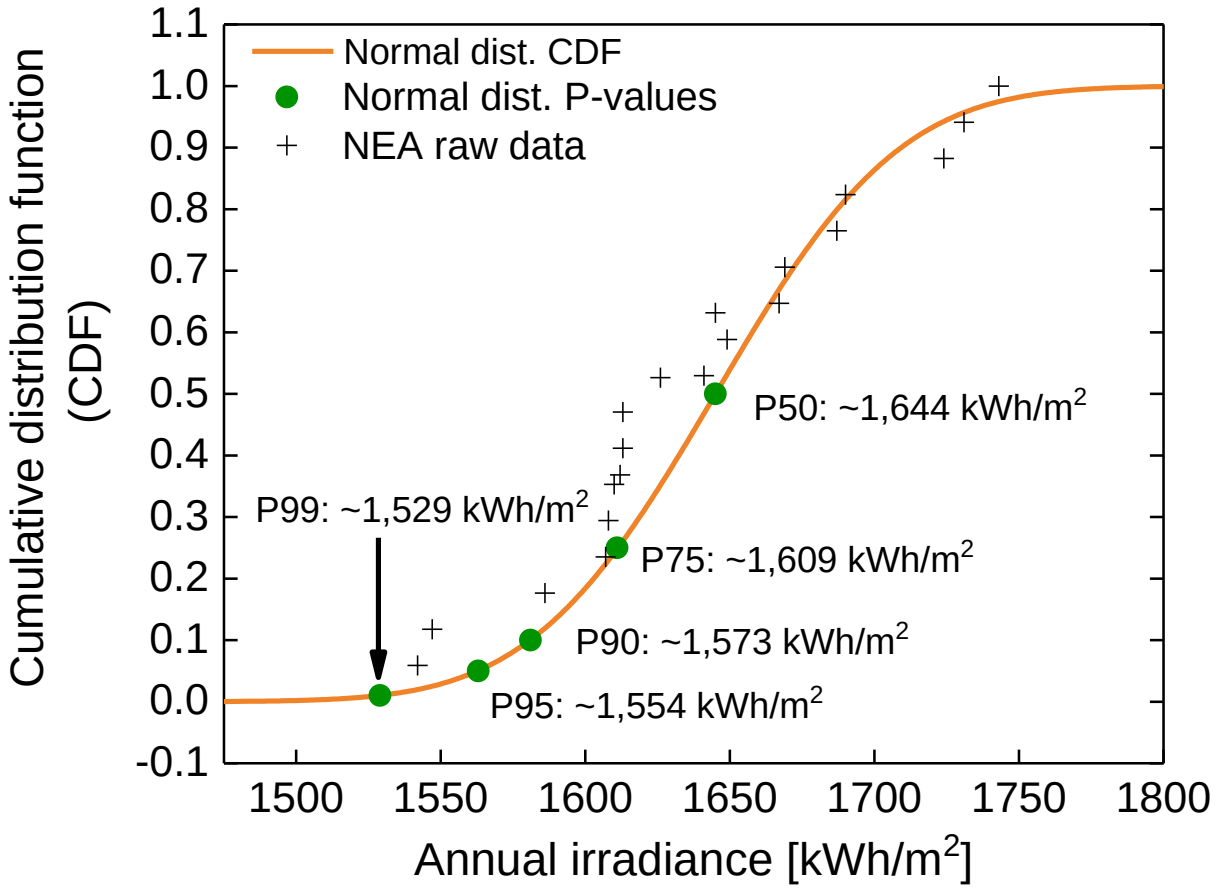
Irradiance resource in Singapore (1)

Exceedance probability risk assessment is important



Example:

A P90 value of ~1,573 kWh/m^2 means that there is a 90% likelihood that the annual irradiance resource will be greater than 1,573 kWh/m^2.

Data source: National Environment Agency (NEA), monthly data from 1991-2000, 2010-2018, Changi Met. Station (S24), irradiance resource varies among different locations in Singapore and between different sensor technologies and level of maintenance. P-values shown are empirical figures

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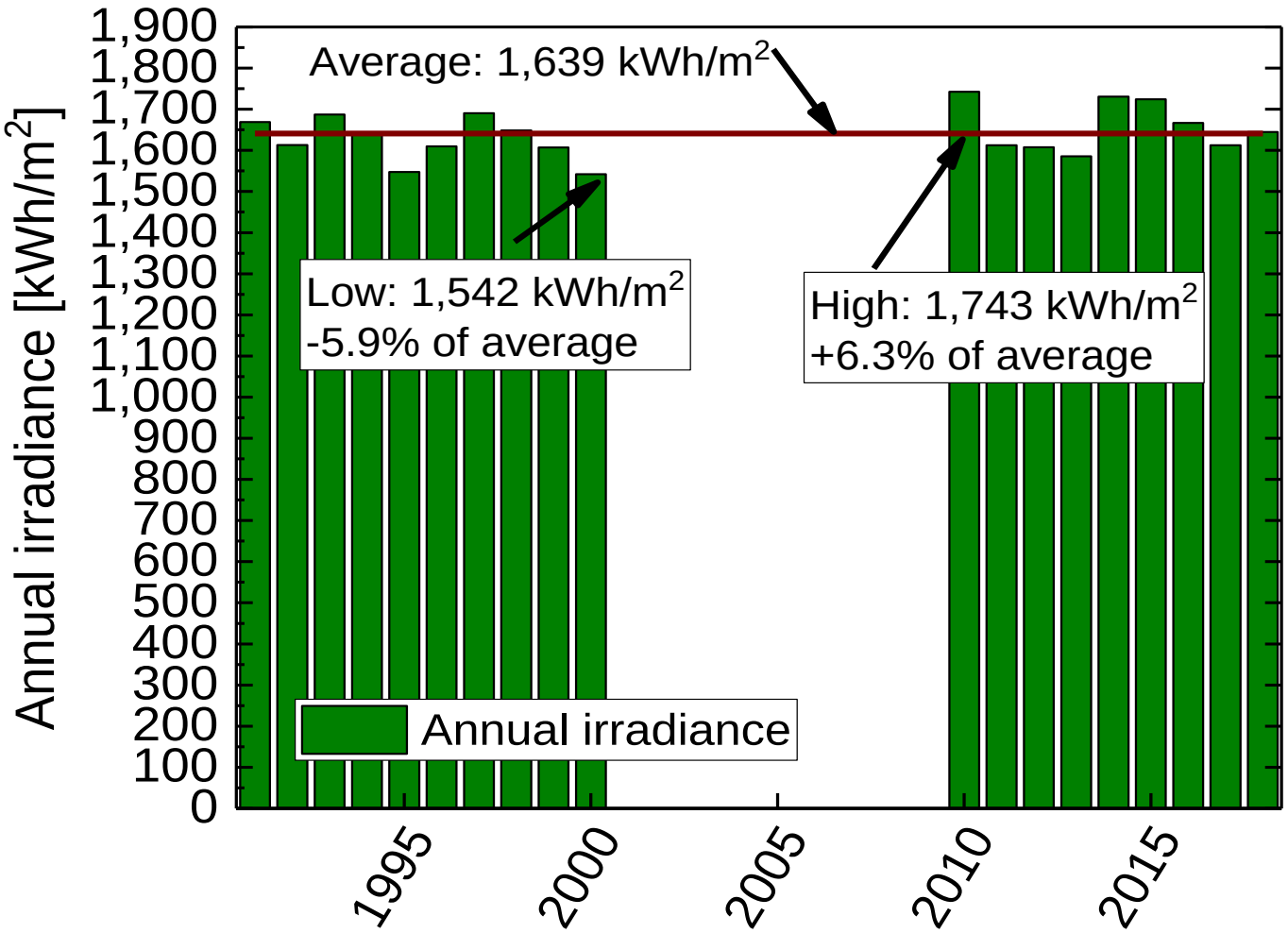
Irradiance resource in Singapore (2)

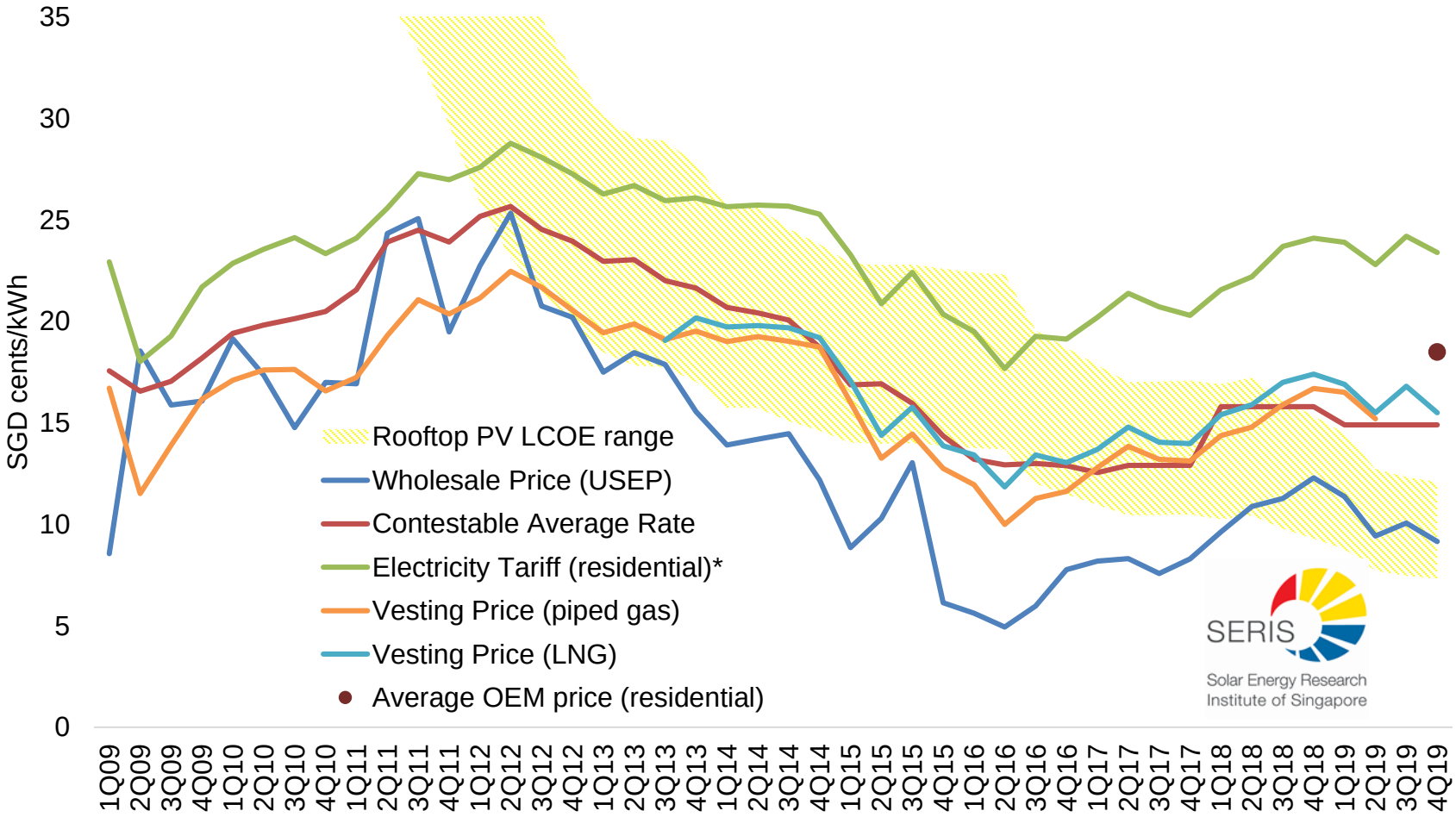


Data source: National Environment Agency (NEA), data from 1991-2000, 2010-2018, Changi Met. Station (S24)

5. Future electricity price scenarios

Solar PV competitiveness

Dependent on project size (eco. of scale) and future electricity prices



Data source: EMA, SP Services, EMC, LCOE range based on SERIS estimates

* OEM = open electricity market (fixed, 12-month contract duration, residential customers)

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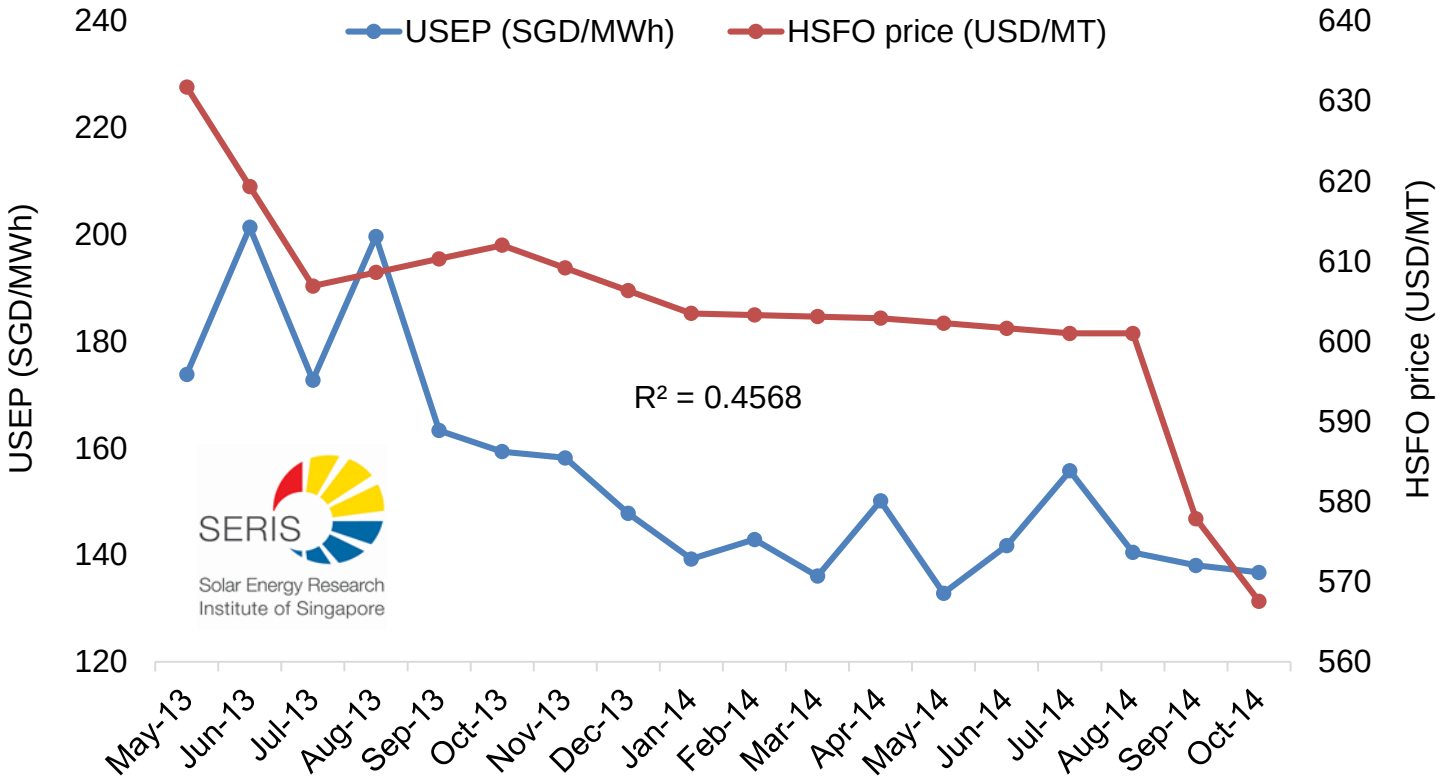
USEP correlation: HSFO*

Since the start of the LNG terminal (May-13)

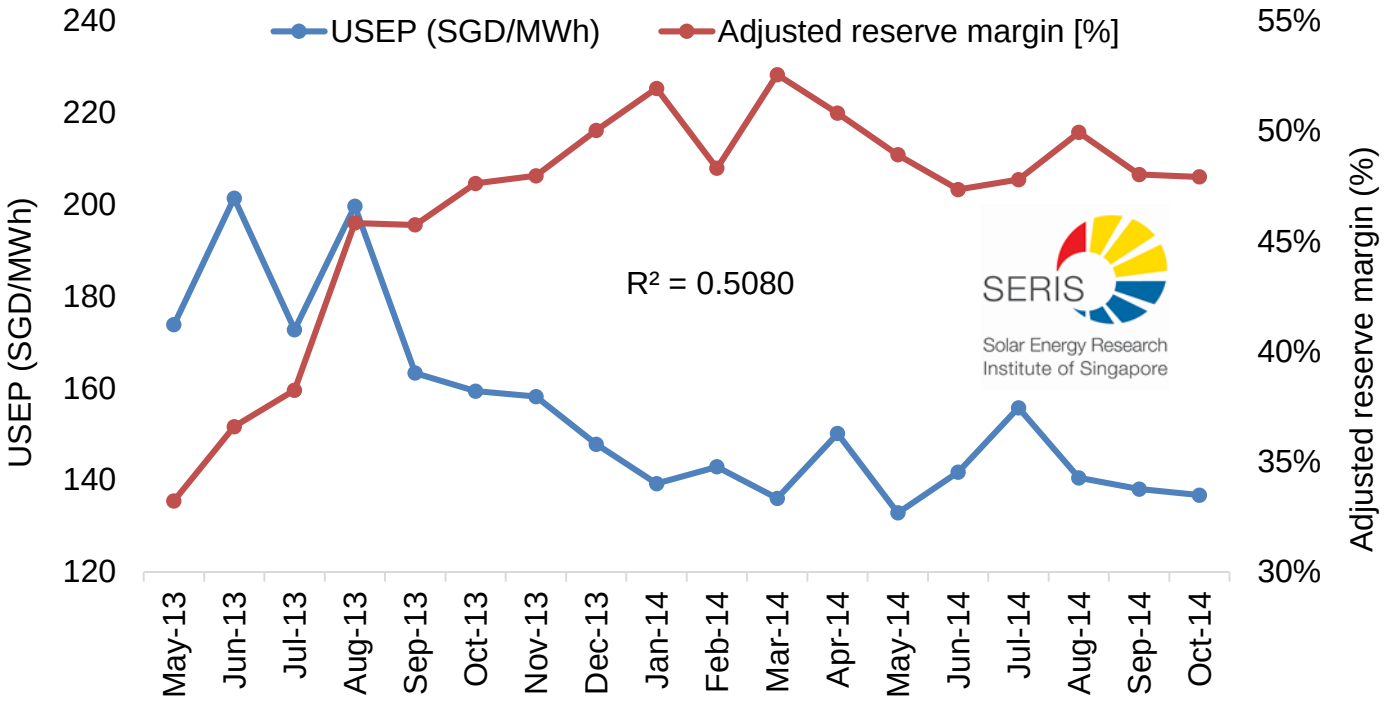


- The correlation between USEP and HSFO is impacted by the fact that the increasing oversupply situation had a stronger influence on USEP especially in the first half of the period

Data source: EMC, Singapore Power (vesting price information). *High-Sulfur Fuel Oil

USEP correlation: reserve margin*

Since the start of the LNG terminal (May-13)



- The correlation between USEP and reserve margin was higher in the first part of the period. Later the influence of fuel cost appeared to become stronger.
- Both parameters, fuel cost and reserve margin, are seen as the two strongest drivers for future USEP price development in the medium to long-term.

Data source: EMC, EMA. *Adjusted by excluding 2.7 GW of steam turbine power plants

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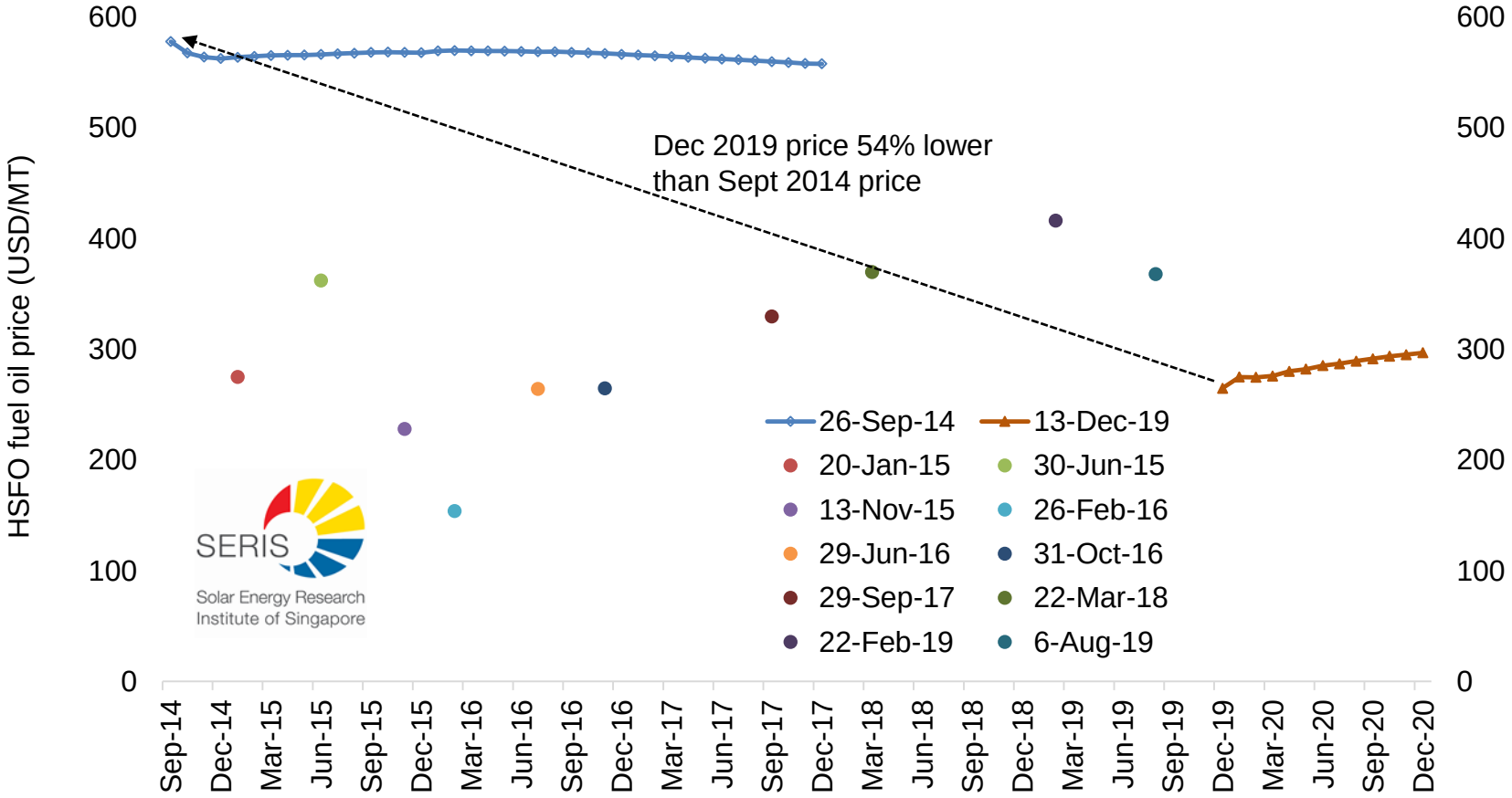
Pipeline gas benchmark: HSFO*

Forward price curve



- Since end 2019 the HSFO forward price curve is upward sloping

Data source: CME Group, “Singapore fuel oil 180 cst (Platts) futures settlements”. *High-Sulfur Fuel Oil

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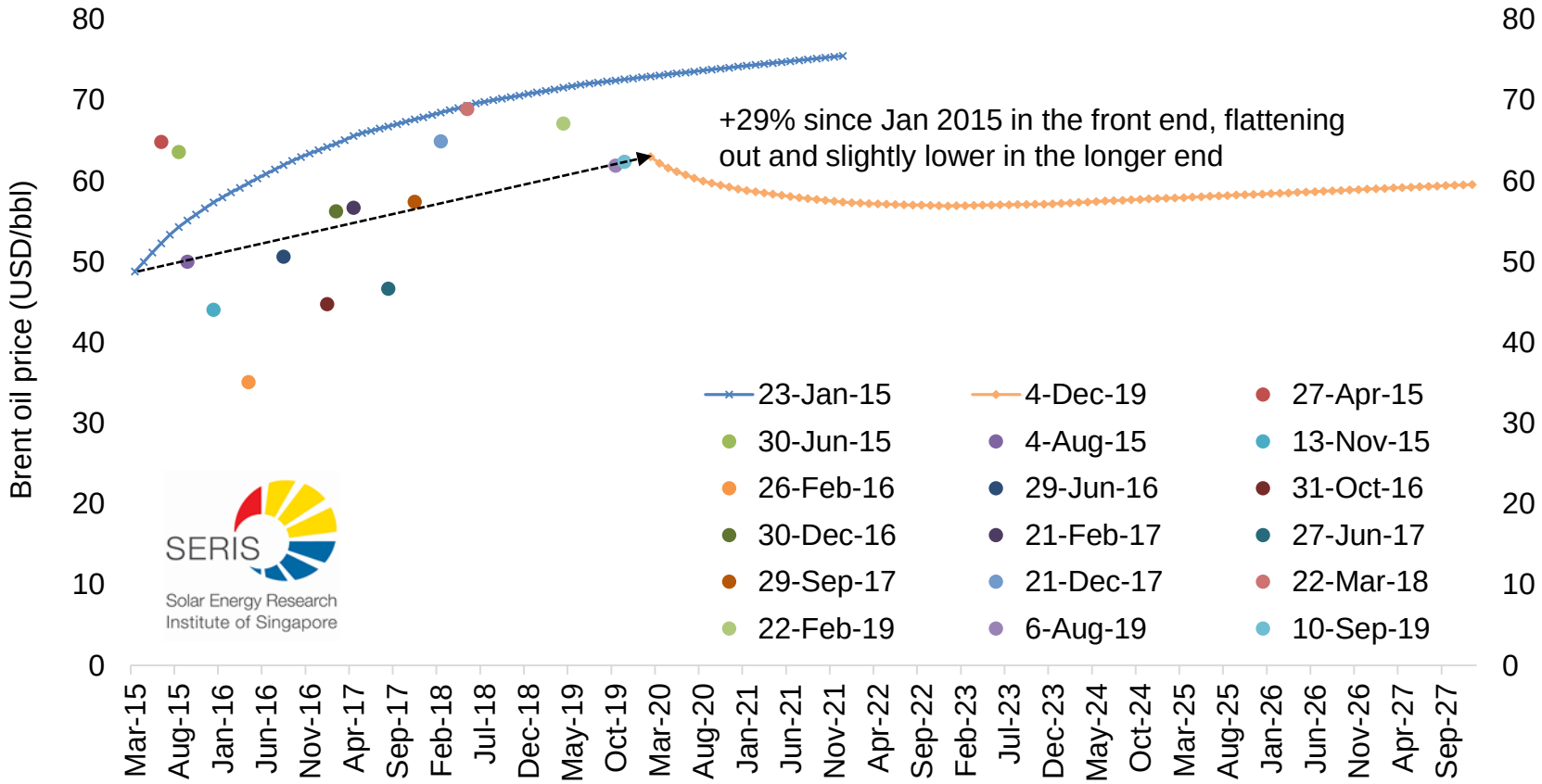
LNG gas benchmark: Brent oil price

Forward price curve



- Brent forward price curve has changed its upward sloping curve in the end of 2016; prices flattening out in the longer end

Data source: CME Group, “Brent crude oil futures settlements”

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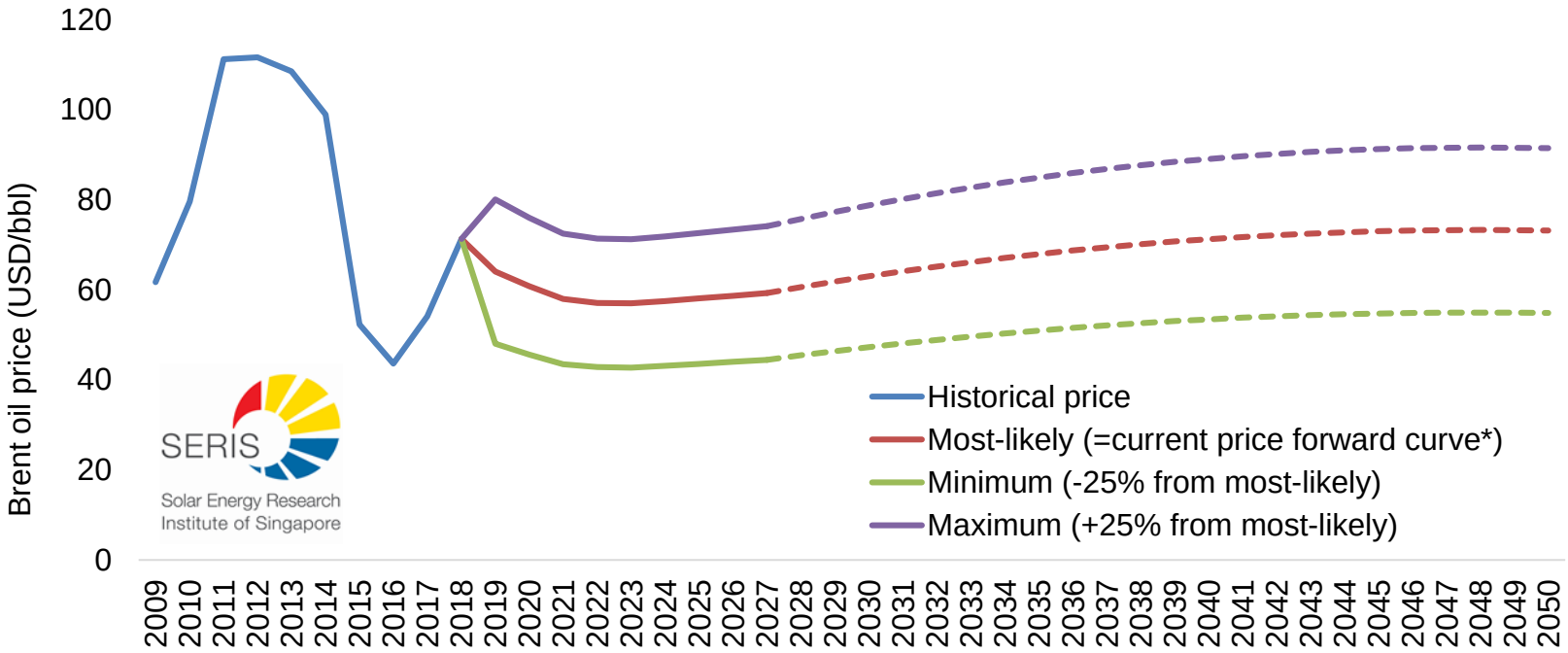
Future oil price scenarios*

Assumed to be a key driver for the future underlying fuel cost of the marginal power plant, which is assumed to be LNG gas fueled

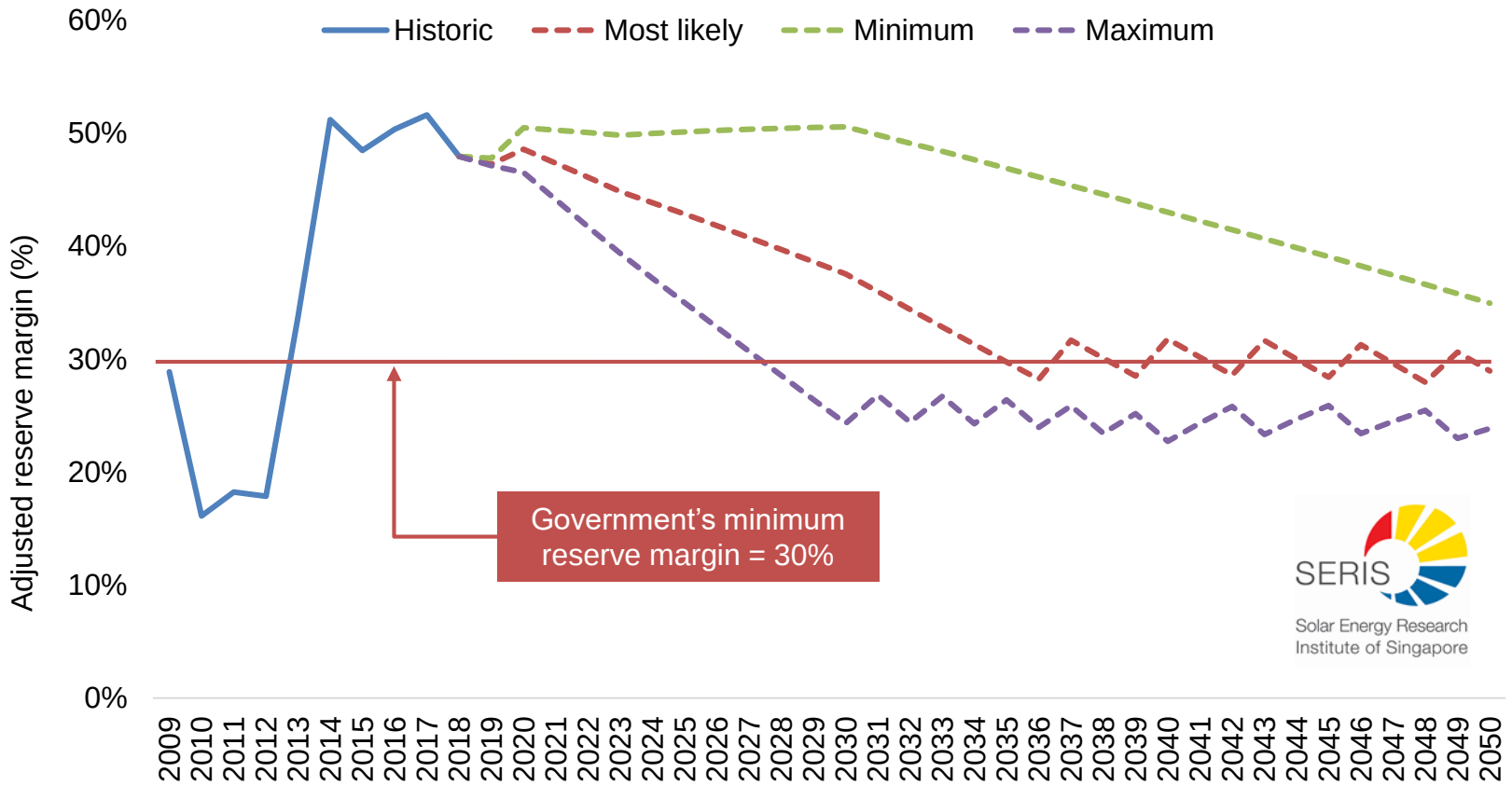


- Scenarios are based on Brent oil price forward curve changes until 2027*, +25% for the maximum scenario, -25% for the minimum scenario; thereafter following EIA % change projections (2050 ref case from Jan 2019)

Data source: EIA, CME Group, “Brent crude oil futures settlements”. *As per 04-Dec-2019 Brent forward price curve

Adjusted reserve margin scenarios

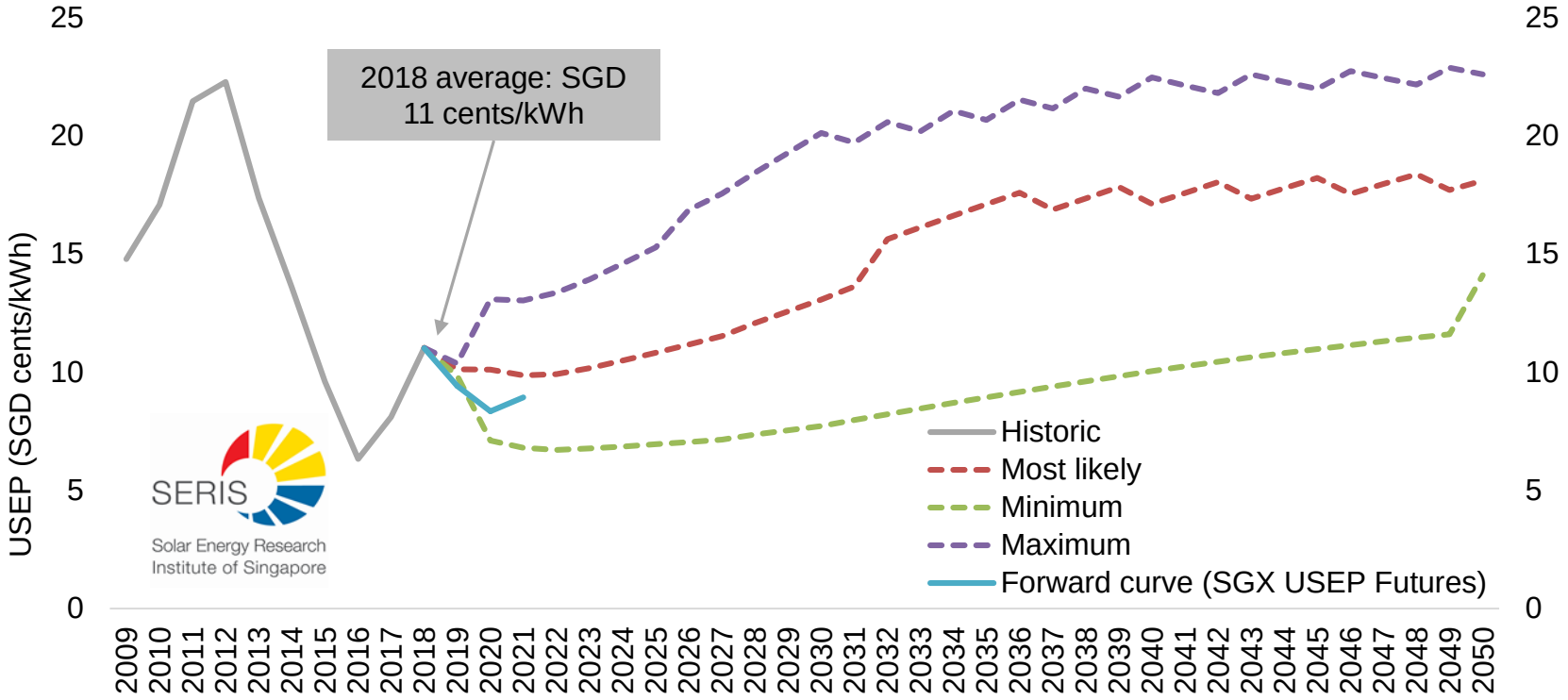
The supply/demand outlook of the sector remains a key factor too



- Scenarios are based on peak demand growth (1%, 1.5% and 2.1%), peak shaving by PV (50% of different capacity addition scenarios), future CCGT addition to prevent reserve margin < 30% (< 25% for maximum scenario)

Wholesale electricity price scenarios*

Uniform Singapore Energy Price (USEP)

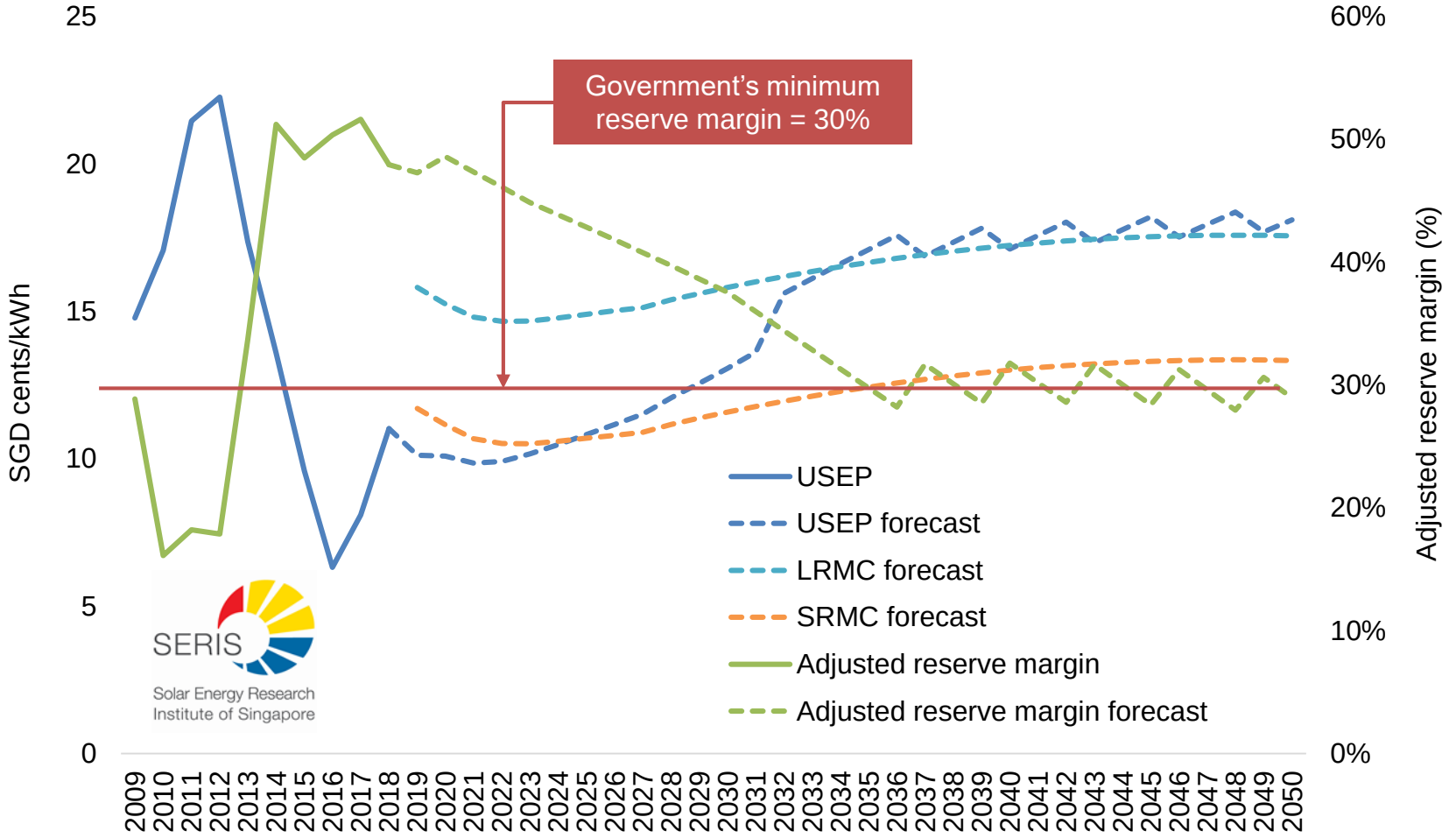


- The addition of bulky new gas power plants to prevent the reserve margin to fall below 30% (25% for the maximum scenario) causes the spikes
- Carbon tax of 5 SGD/tCO_2 is included 2020 onwards, increasing gradually to 12.5 SGD/tCO_2 during 2023-2030, flat thereafter (using 418.8 kgCO_2/MWh)

*As per 4-Dec-2019 Brent forward price curve, Spot Brent oil price: 63 USD/barrel

Most-likely USEP scenario*

USEP/reserve margin compared to LRMC/SRMC of a new CCGT



*As per 4-Dec-2019 Brent forward price curve, Spot Brent oil price: 63 USD/barrel

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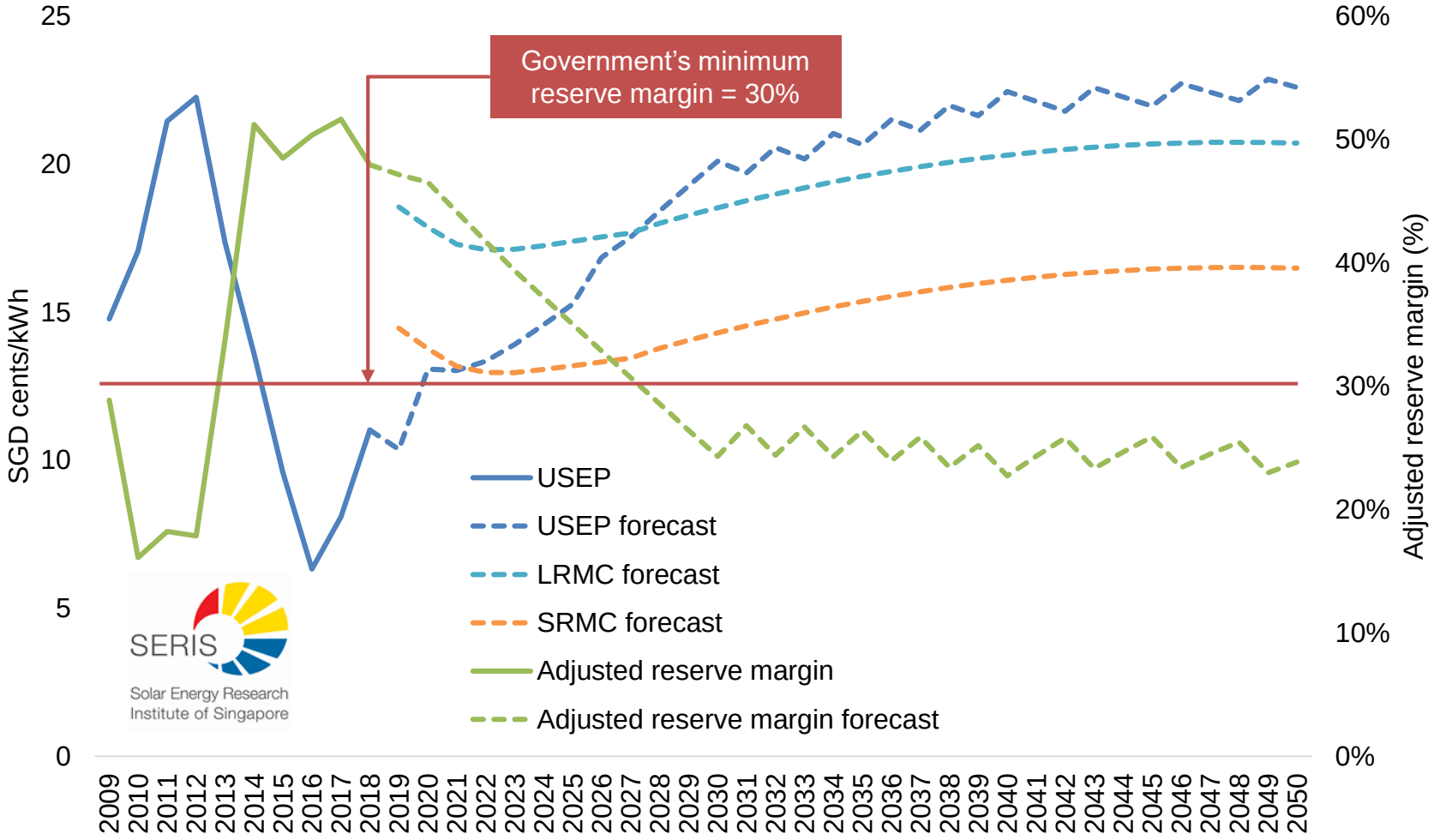
Maximum USEP scenario*

USEP/reserve margin compared to LRMC/SRMC of a new CCGT



*As per 4-Dec-2019 Brent forward price curve, Spot Brent oil price: 63 USD/barrel

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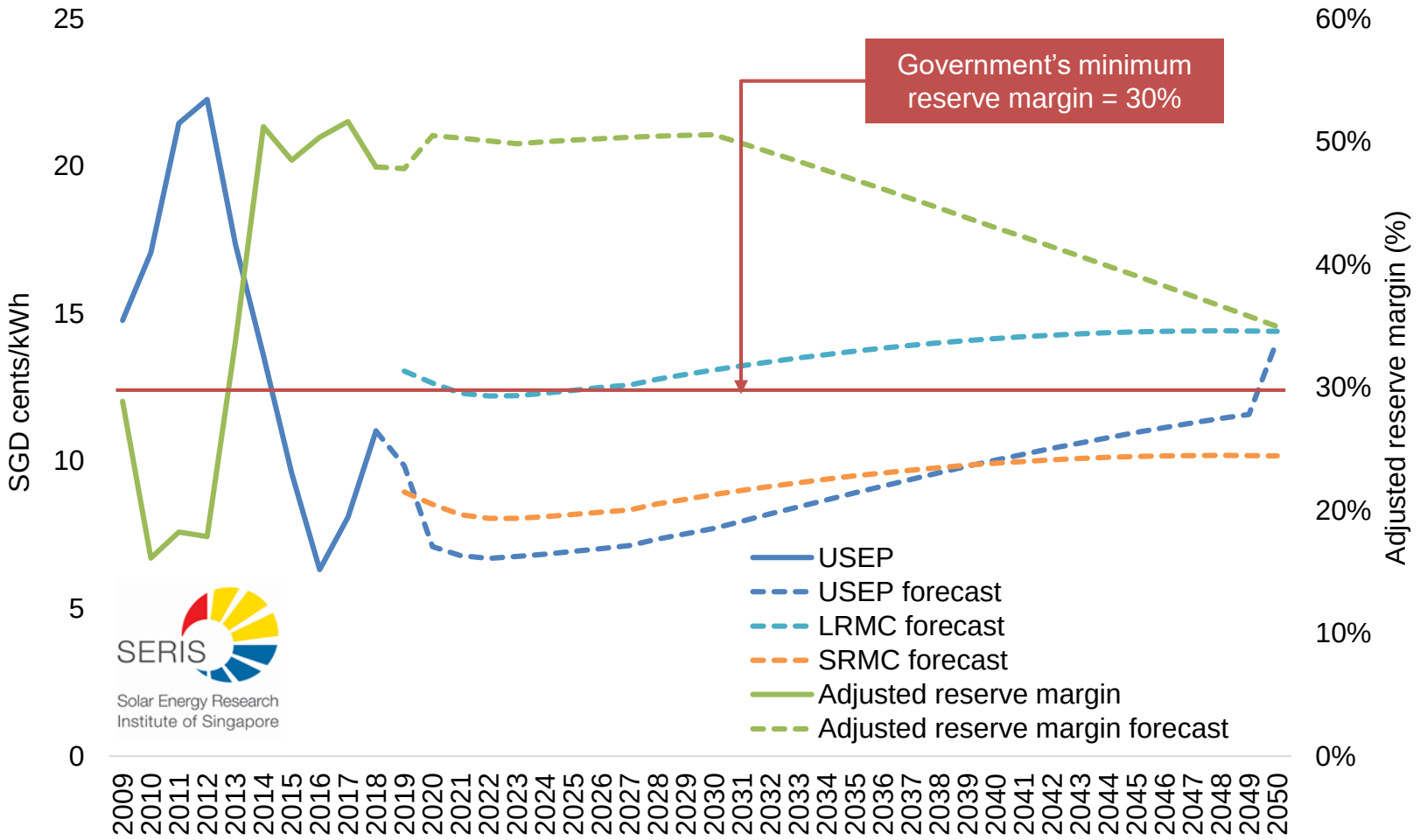
Minimum USEP scenario*

USEP/reserve margin compared to LRMC/SRMC of a new CCGT



*As per 4-Dec-2019 Brent forward price curve, Spot Brent oil price: 63 USD/barrel

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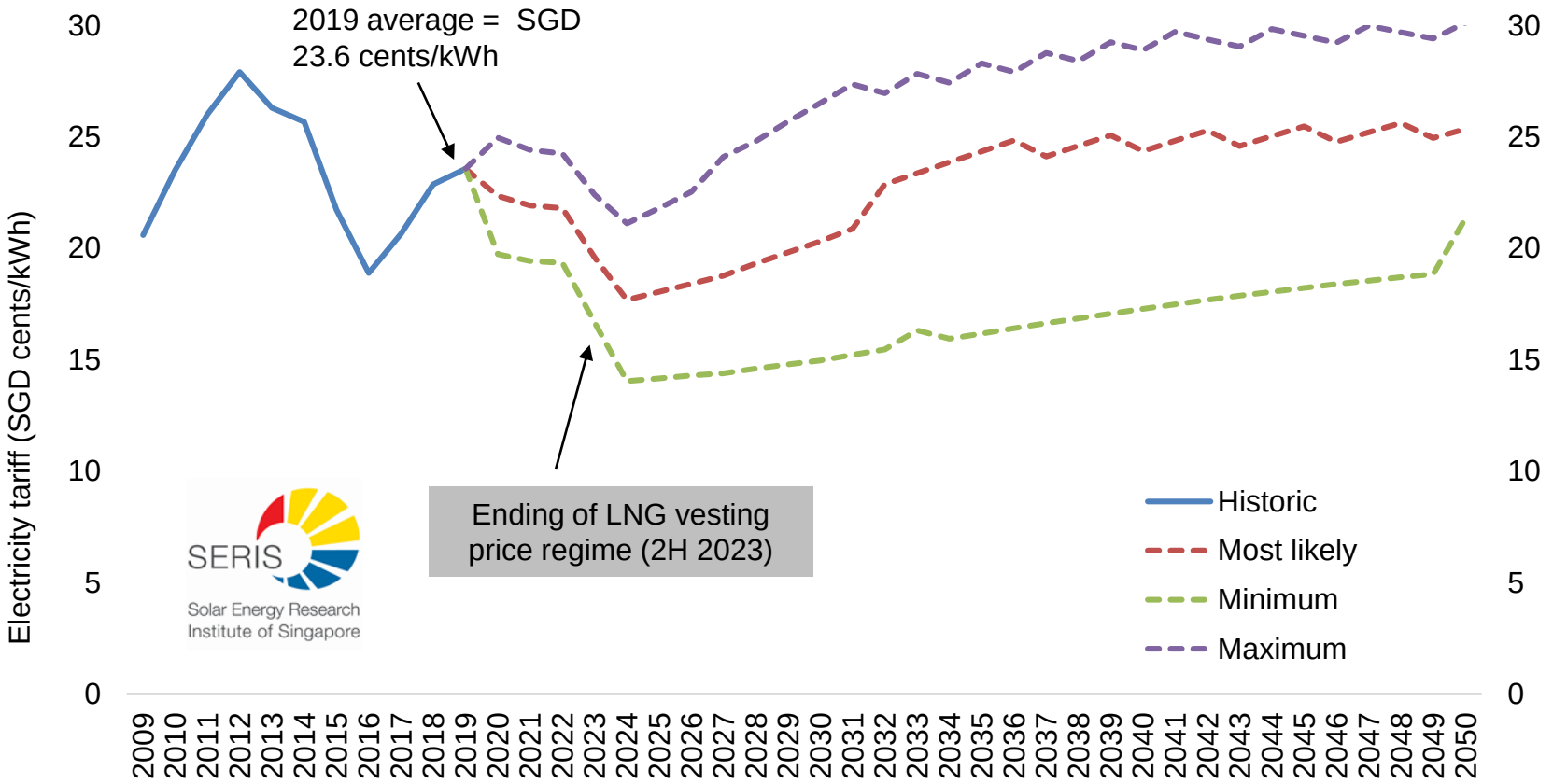
Electricity tariff scenarios*



- Assumption: link to LNG vesting price supports the tariff until July 2023, thereafter energy cost based on 100% prevailing USEP, grid fee of SGD 5.4 cents/kWh assumed to increase by 0.5% p.a. until 2026

*As per 4-Dec-2019 Brent forward price curve, Spot Brent oil price: 63 USD/barrel

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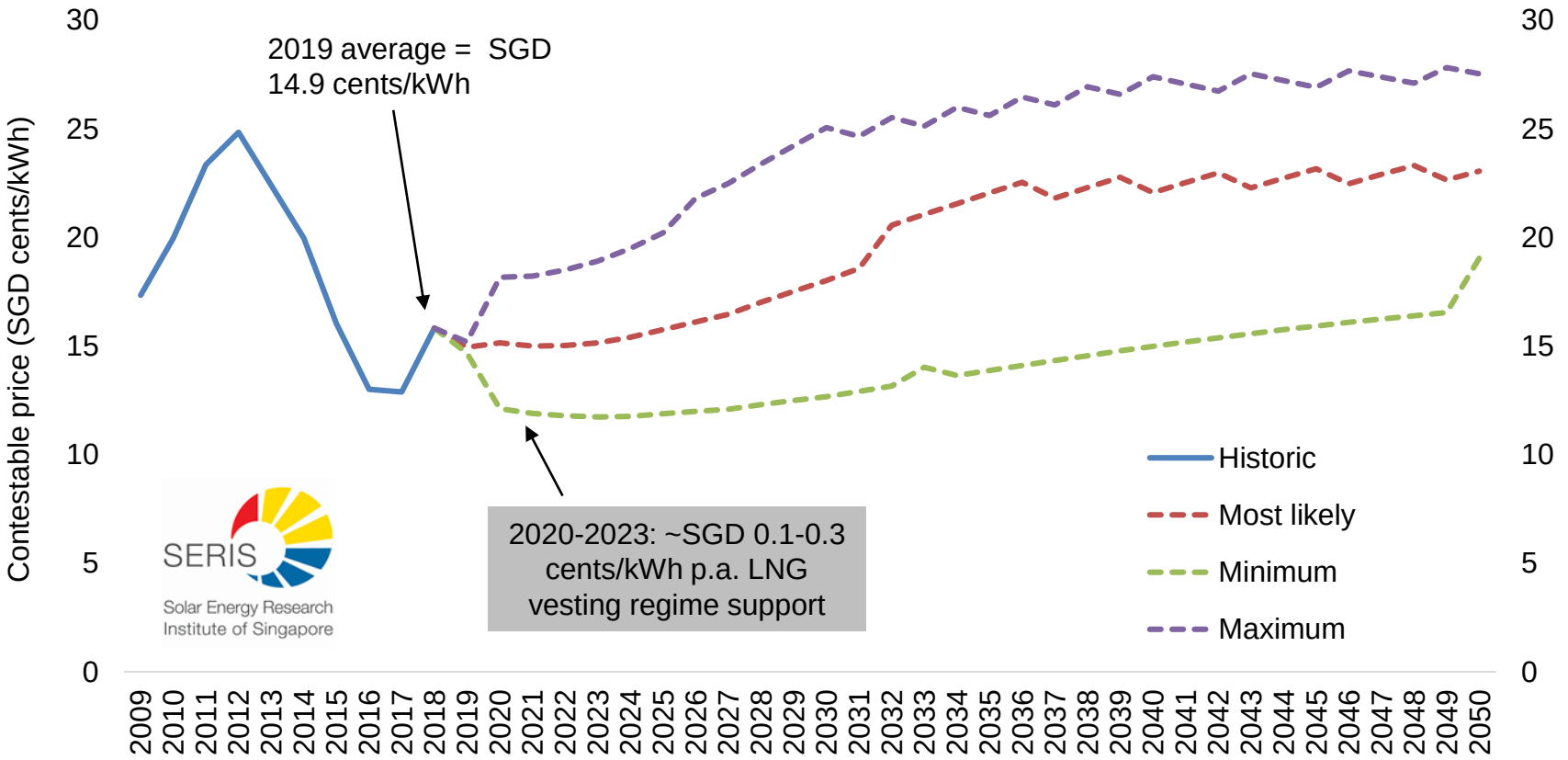
Contestable price scenarios*



- Assumption: energy portion linked to USEP, grid fee of SGD 3.6 cents/kWh increased by 0.5% p.a. until 2026, other fees of SGD 1.2 cents/kWh remain constant, annual LNG vesting price support added SGD 0.1-0.3 cents/kWh p.a.

*As per 4-Dec-2019 Brent forward price curve, Spot Brent oil price: 63 USD/barrel

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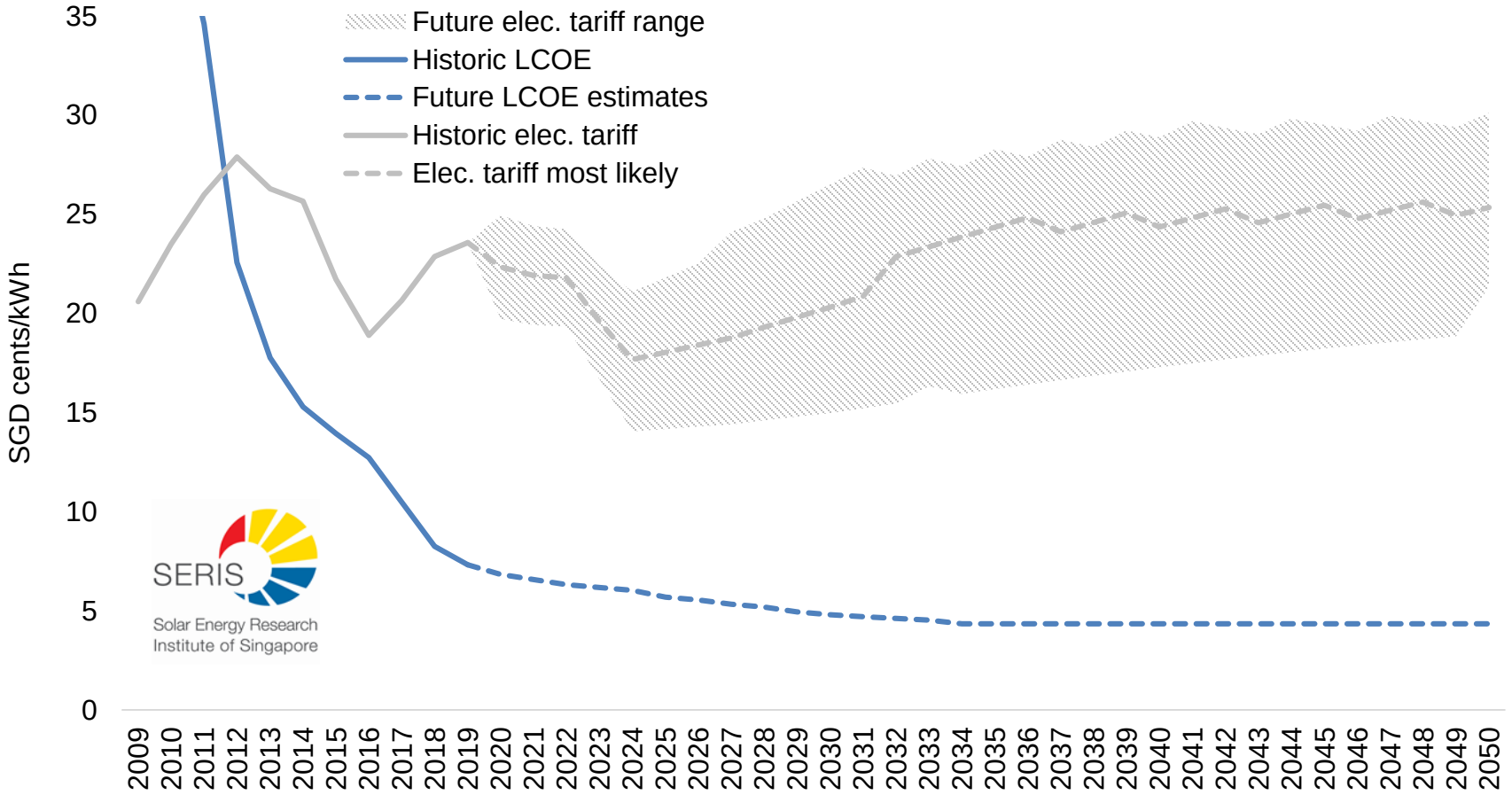
6. Grid parity and economic viability analysis

Grid parity for Industrial 1MWp system

Reached when compared to the electricity tariff scenarios*

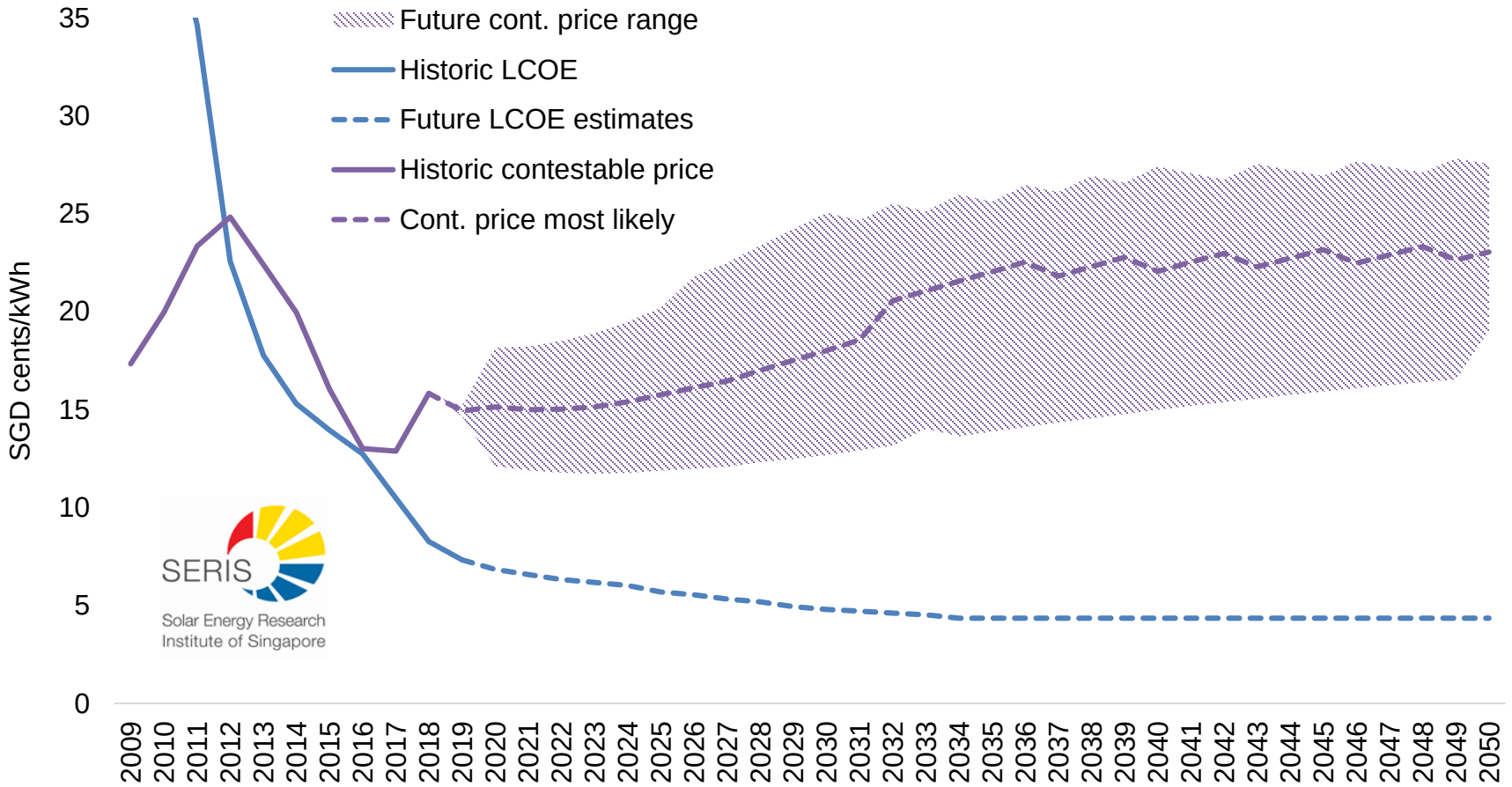


- Historic LCOE based on Chinese module price decline (www.solarserver.com)

*As per 4-Dec-2019 Brent forward price curve, Spot Brent oil price: 63 USD/barrel

Grid parity for Industrial 1MWp system

Reached when compared to average contestable price scenarios*



- Historic LCOE based on Chinese module price decline (www.solarserver.com)

*As per 4-Dec-2019 Brent forward price curve, Spot Brent oil price: 63 USD/barrel

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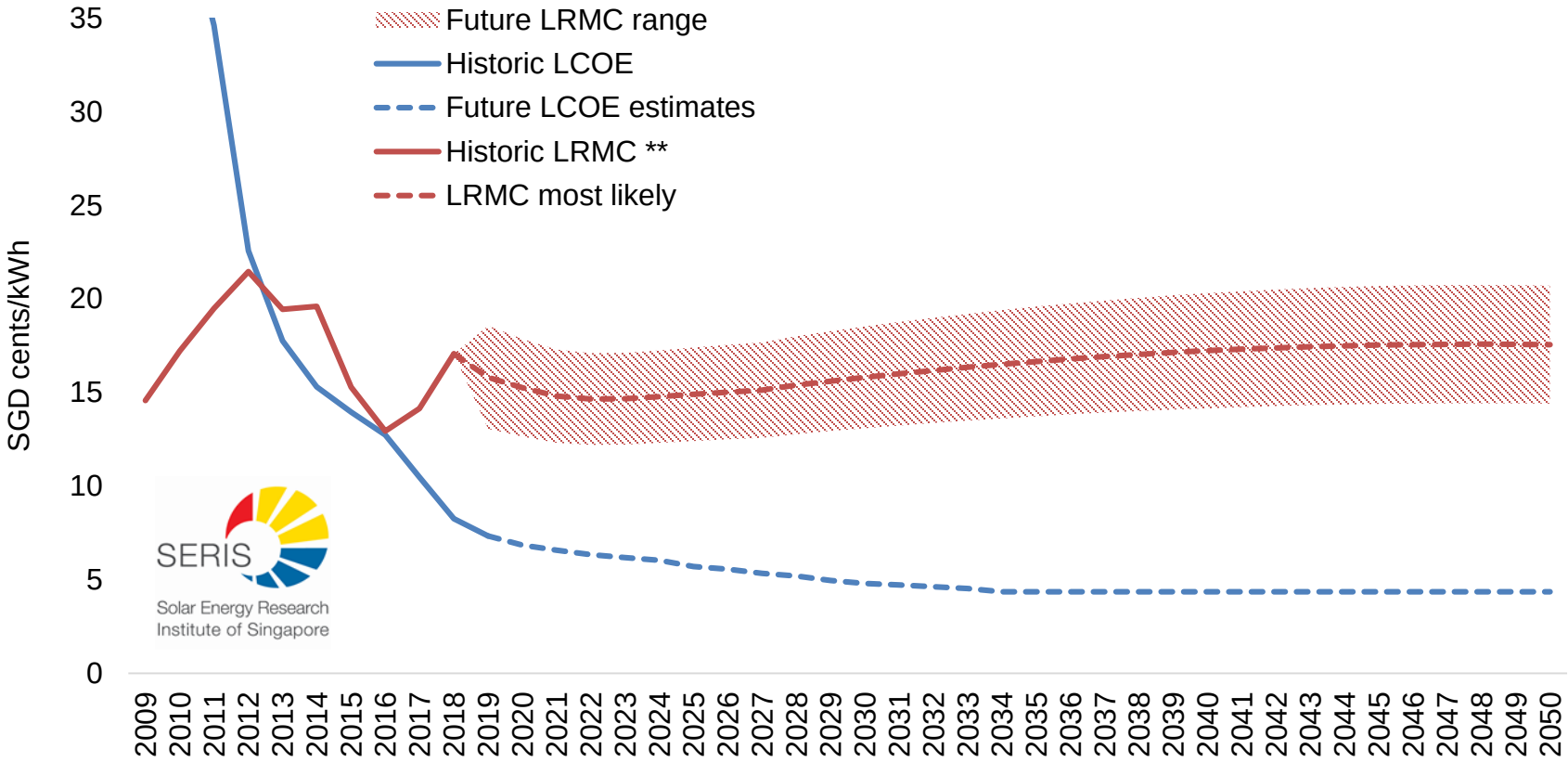
Grid parity for Industrial 1MWp system

Reached when compared to the LRMC of an new gas-fired CCGT*



- Historic LCOE based on Chinese module price decline (www.solarserver.com)

*As per 4-Dec-2019 Brent forward price curve, Spot Brent oil price: 63 USD/barrel

**Long-run marginal cost (LRMC), combined cycle gas turbine (CCGT), historic based until 2013 on allocated vesting prices, 2014 onwards on LNG vesting price

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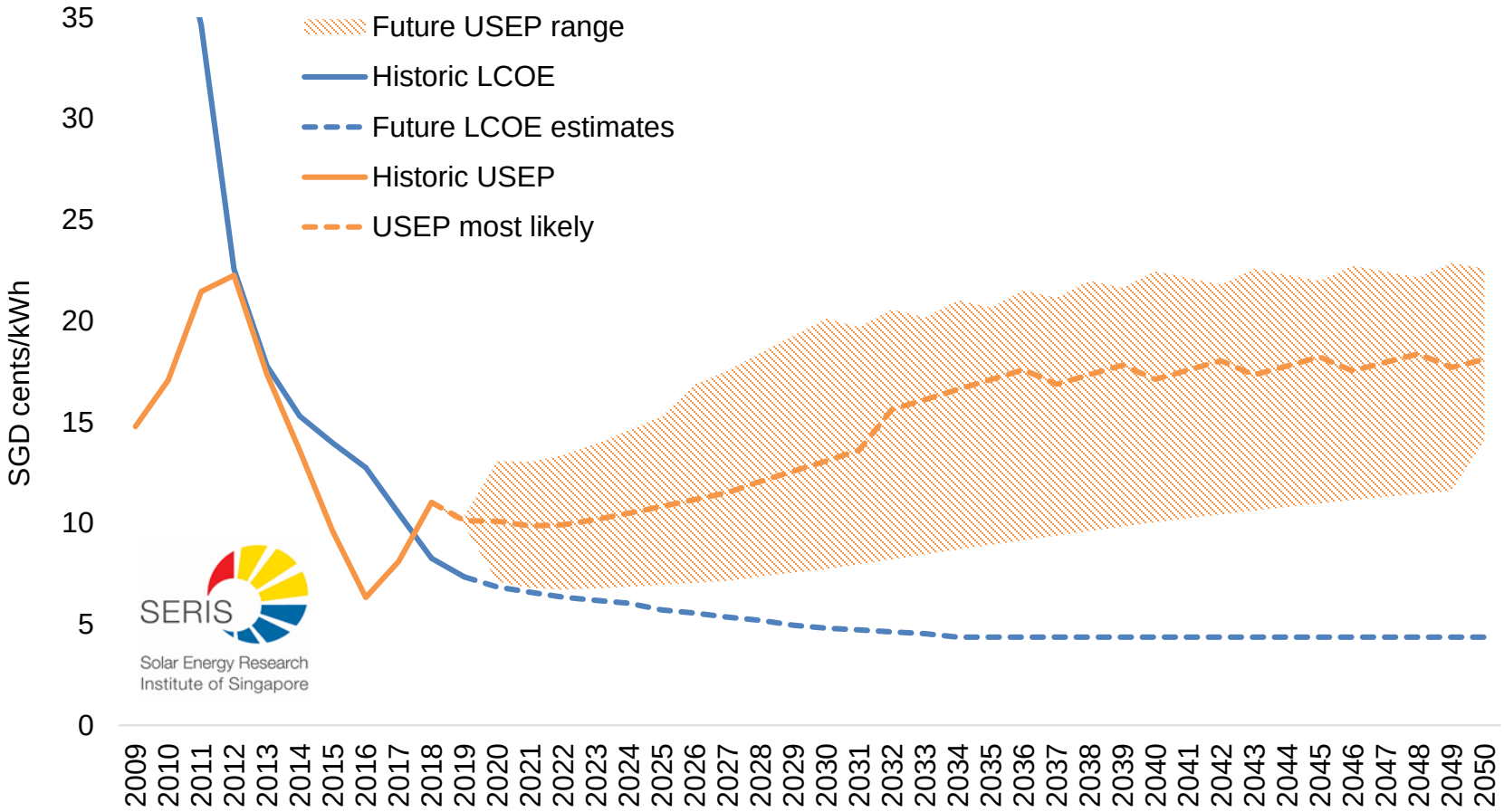
Grid parity for Industrial 1MWp system

Reached when compared to wholesale price (USEP) scenarios*



- Historic LCOE based on Chinese module price decline (www.solarserver.com)

*As per 4-Dec-2019 Brent forward price curve, Spot Brent oil price: 63 USD/barrel

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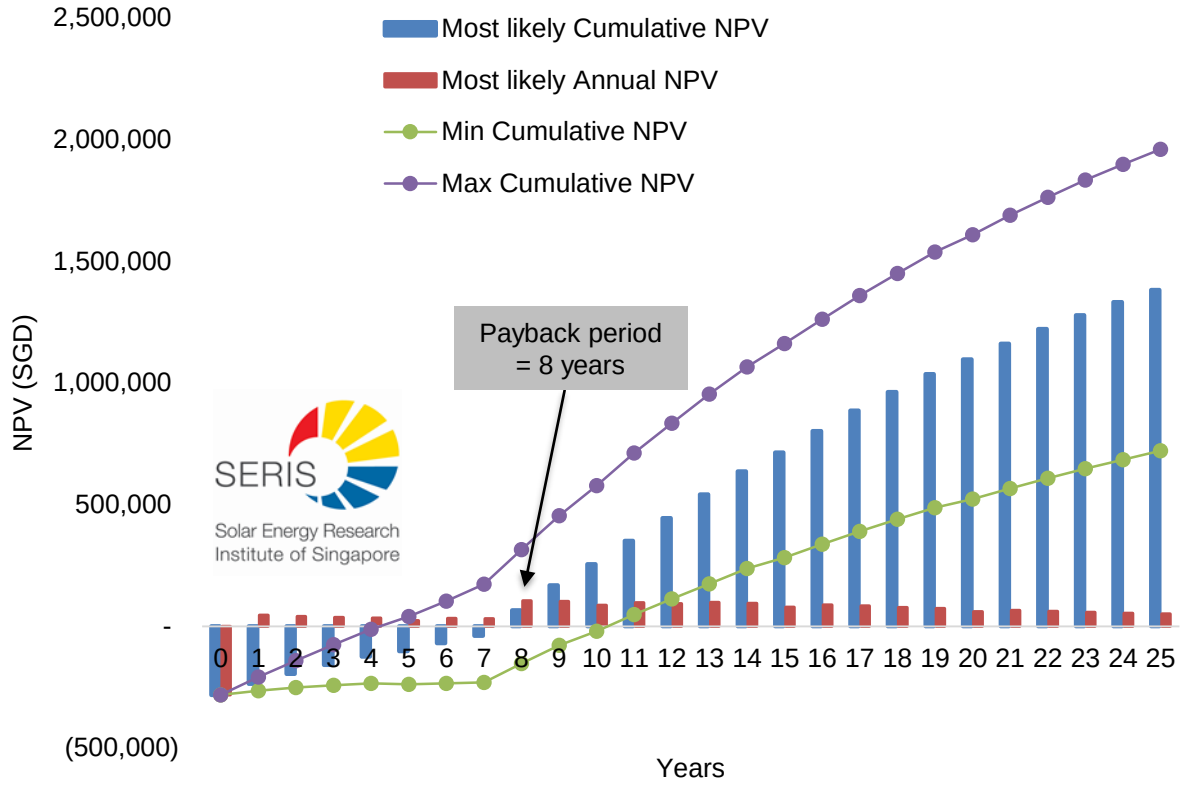
NPV of 1MW$_p$ PV system "self-owned"

- Assumption: base year 0 = 2019, future prices in line with SERIS' contestable client price scenarios*



Equity IRR:
Maximum: 34.0%
Most-likely: 24.7%
Minimum: 16.0%

Project IRR:
Maximum: 21.0%
Most-likely: 16.8%
Minimum: 12.1%

- Discounted payback period can be shortened by ~three years in case loan maturity is extended to 10 years instead of 7 years (most-likely scenario)

*As per 04-Dec-2019 Brent forward price curve, Spot Brent oil price: 63 USD/barrel

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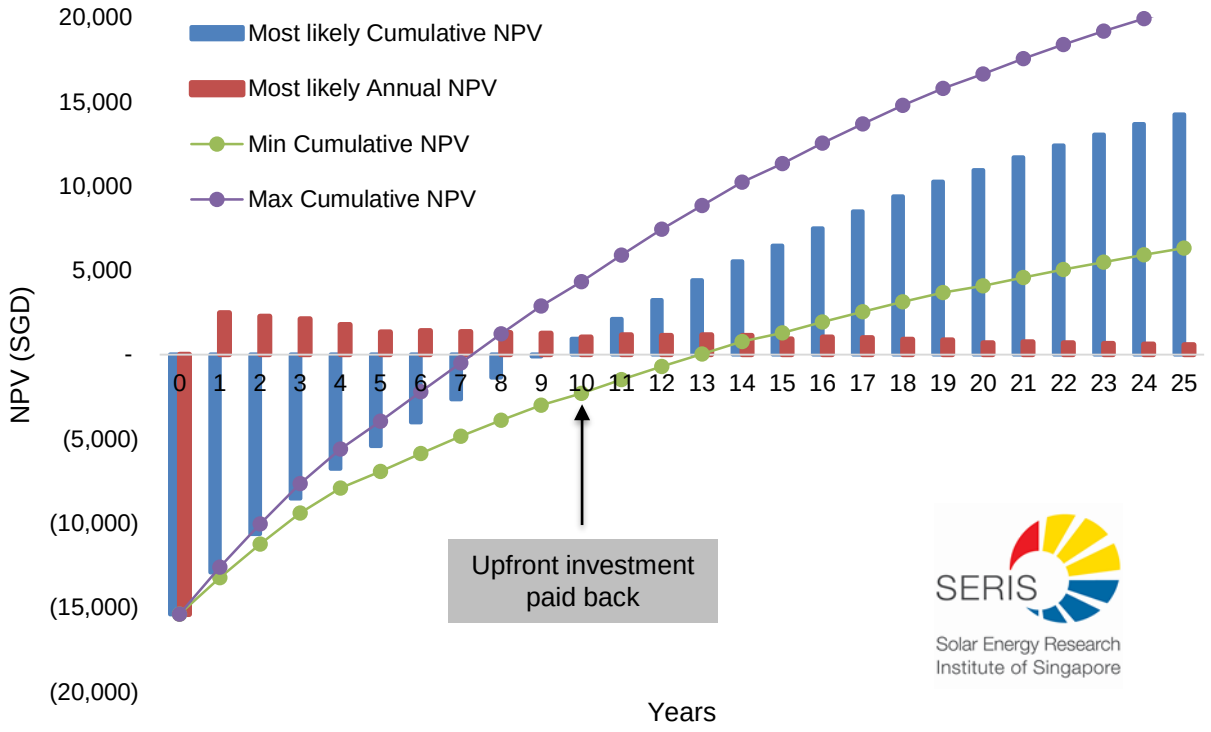
NPV of 10 kW_p PV system "self-owned"

- Assumption: base year 0 = 2019, future prices in line with SERIS' electricity tariff scenarios*



Project IRR:
Maximum: 17.1%
Most-likely: 13.9%
Minimum: 9.8%

- Discounted payback period can be shortened by ~five years in case 50% can be financed by a favorable 20-year residential loan at 3.5% interest rate

*As per 04-Dec-2019 Brent forward price curve, Spot Brent oil price: 63 USD/barrel

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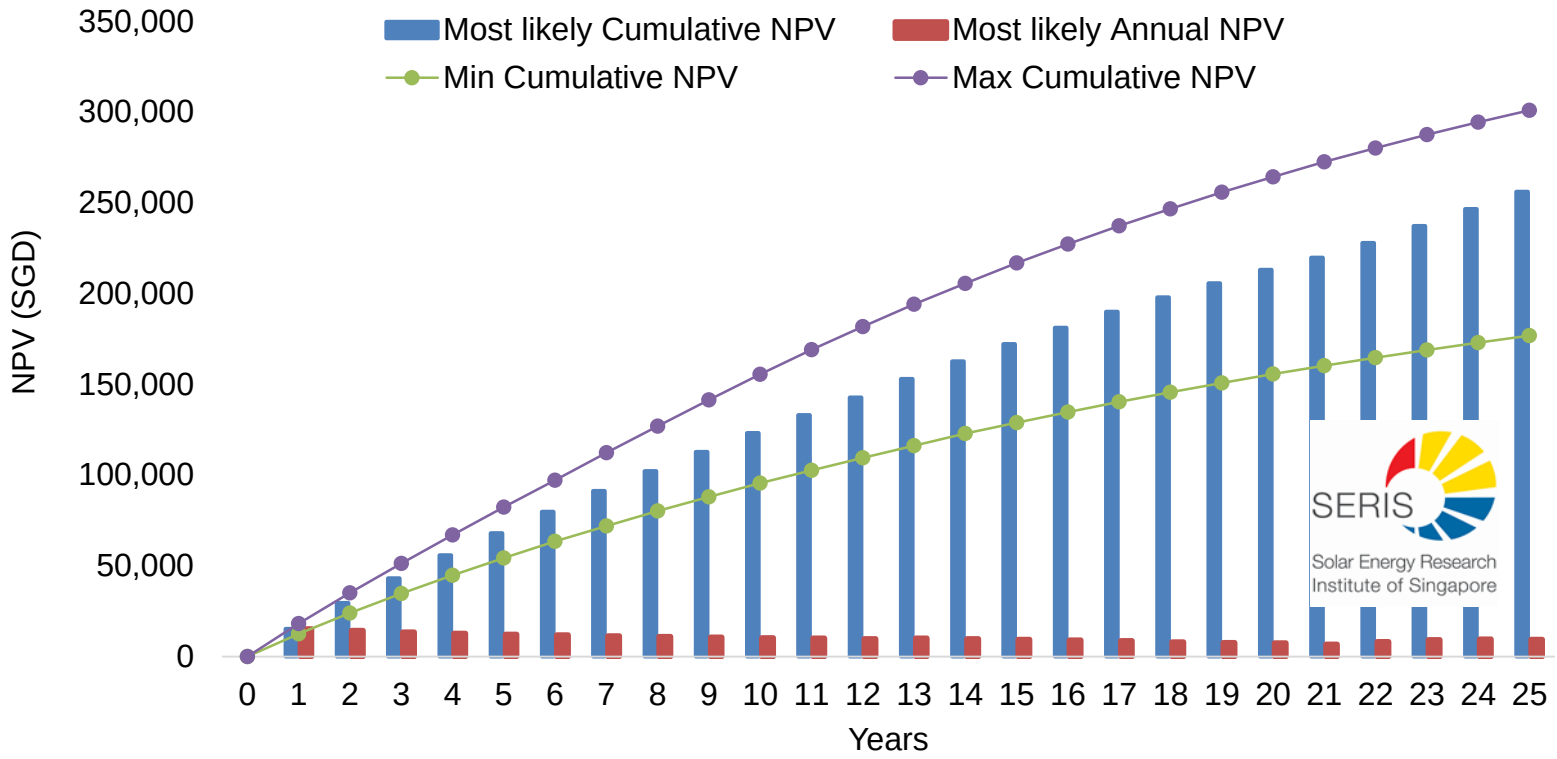
NPV of 1MW$_p$ PV system "PPA"

- Assumption: base year 0 = 2019, industrial customer receives 10% discount on its own contestable client tariff*



- Self-owning model results in higher NPVs, break-even discount rate under the most-likely scenario is ~59%

*As per 04-Dec-2019 Brent forward price curve, Spot Brent oil price: 63 USD/barrel

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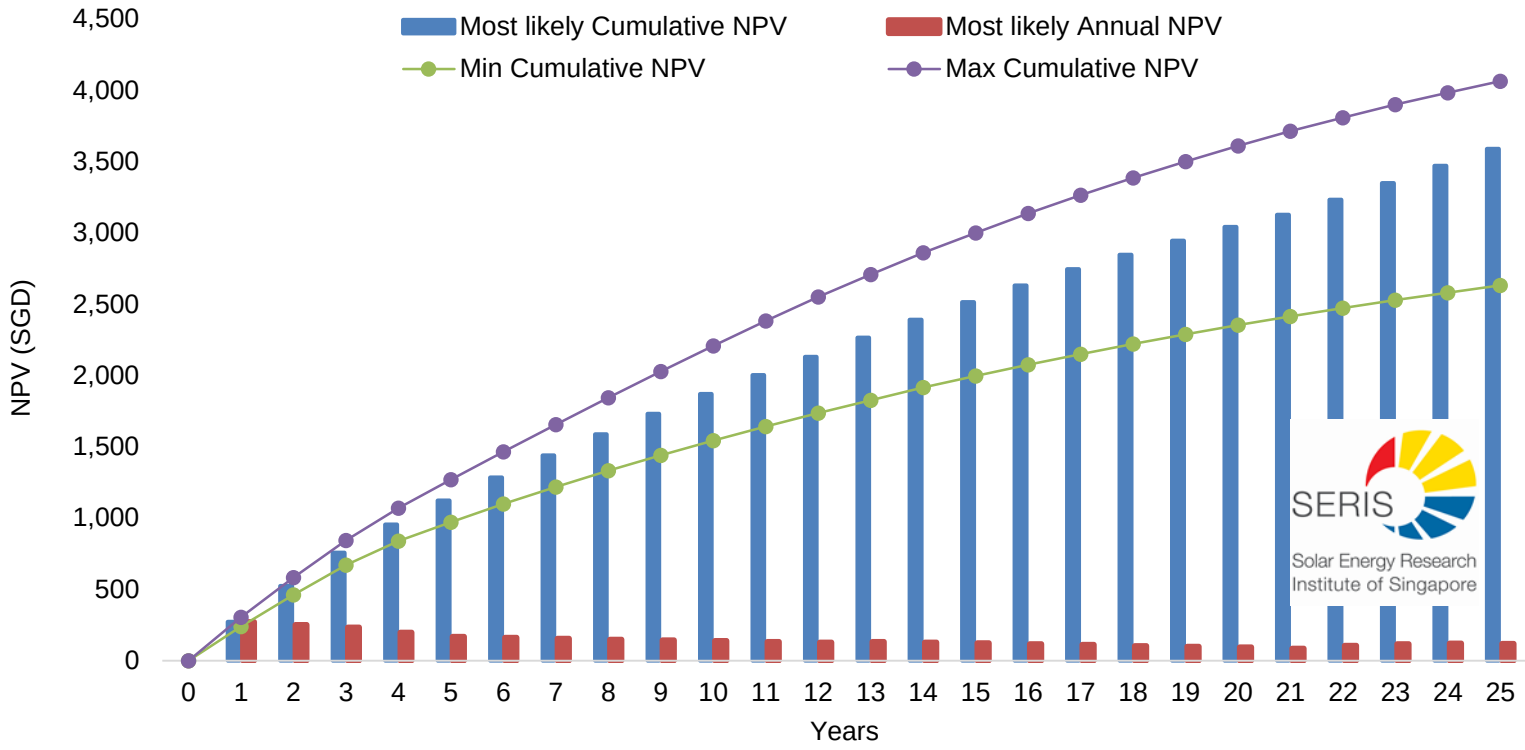
NPV of 10 kW_p PV system "PPA"

- Assumption: base year 0 = 2019, residential customer receives 10% discount on the electricity tariff*

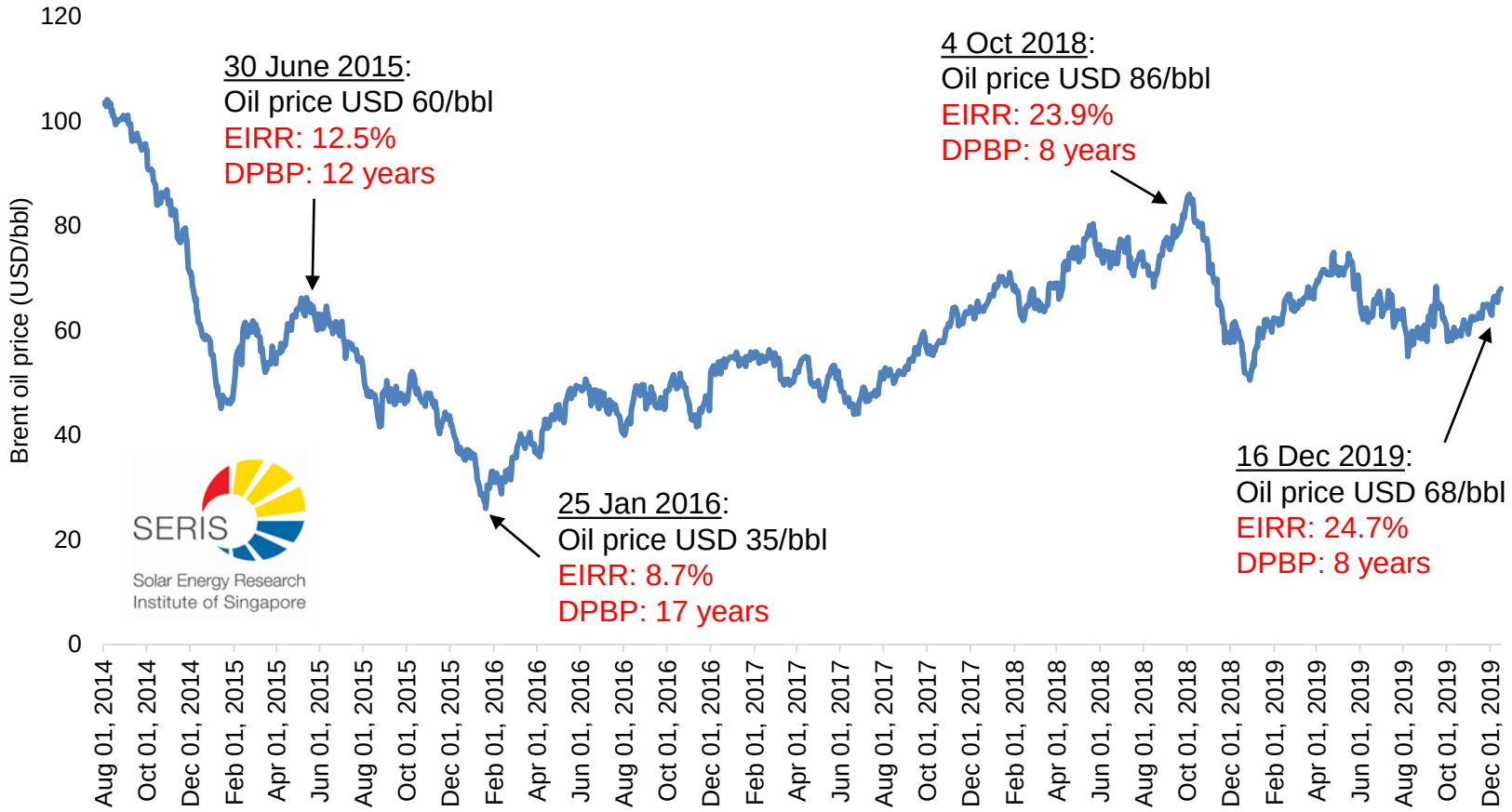


- Self-owning model results in higher NPVs, break-even discount rate for the most-likely scenario is ~41%

*As per 04-Dec-2019 Brent forward price curve, Spot Brent oil price: 63 USD/barrel

Level of oil price matters

Profitability change for a 1MWp PV system at different oil price levels



- Financial viability of solar PV in Singapore also improved with panel prices declining by ~64% since end of 2015

Data source: EIA for Brent oil price until 16-Dec-2019

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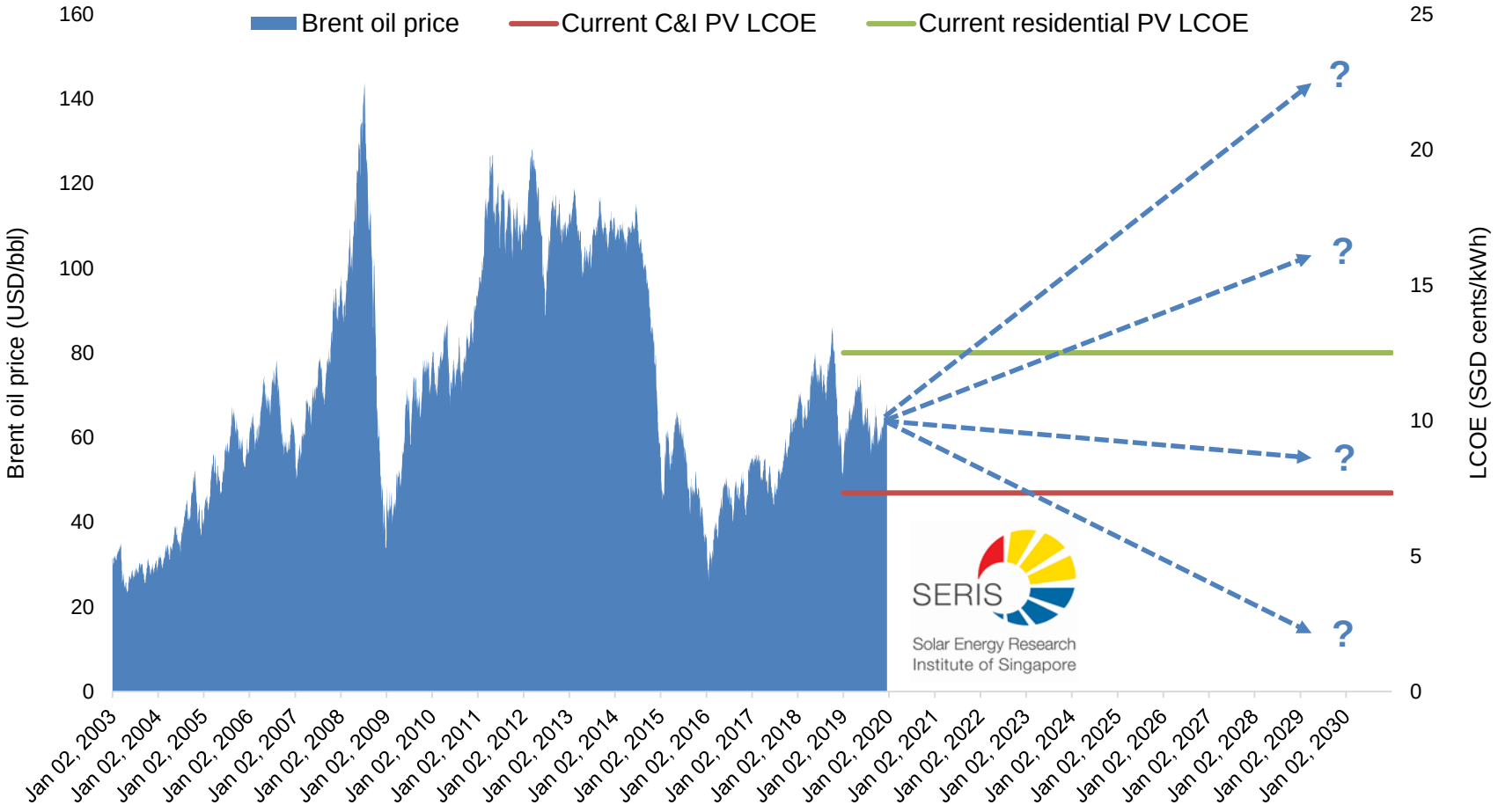
But your electricity cost is locked-in

Solar energy hedges against uncertain future electricity prices influenced by unpredictable oil prices



Data source: EIA for Brent oil price until 16-Dec-2019

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www.solar-respository.sg

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