Centre for Energy and Environmental Markets

UNSW SYDNEY

Historical Market Trend of Distributed Photovoltaic Inverters in Australia

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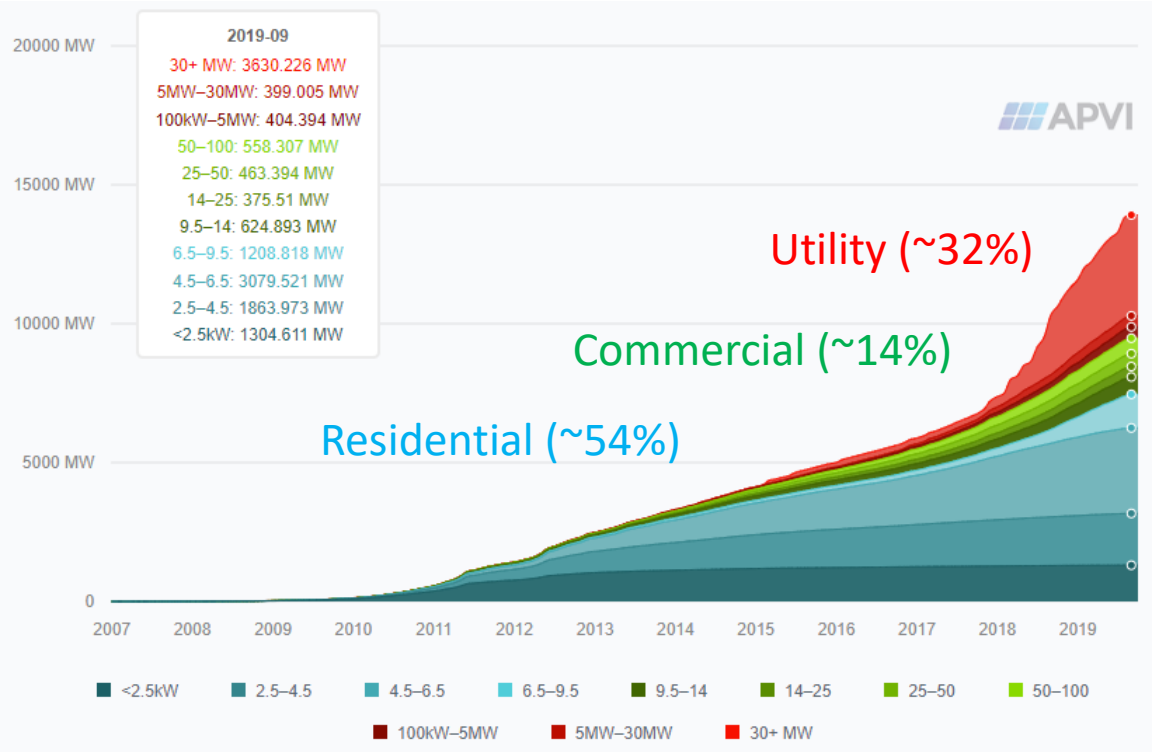
Context

- More than two million distributed PV systems installed in Australia
- Limited data available about inverter market trends and therefore their potential behaviour and impact on the grid
- This study seeks to remedy this gap with regard to inverter specifications including:
  - AC power
  - DC to AC ratio
  - Connection phases
  - Manufacturer



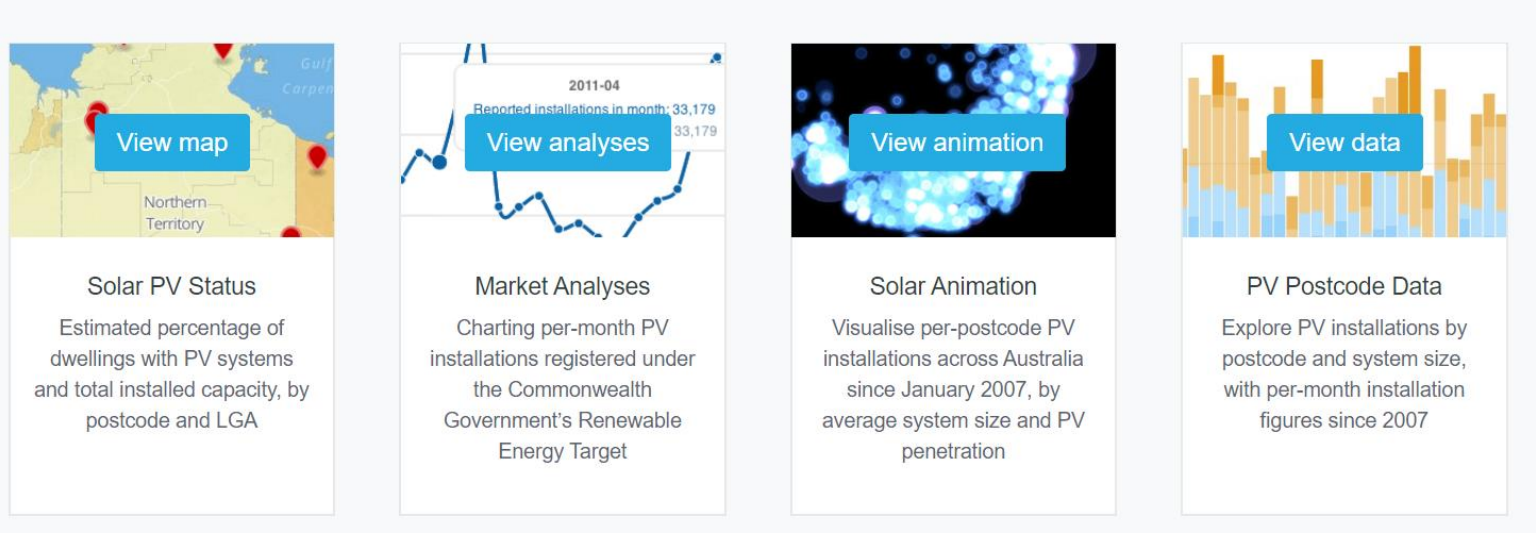
http://pv-map.apvi.org.au/

Motivation

- The results of this study may be useful to a range of stakeholders, including
  - PV installers,
  - inverter manufacturers,
  - distribution network service providers,
  - retailers,
  - and other third parties acting on behalf of consumers,
  - that are seeking to better understand deployment trends and the implications of inverter connection requirements.
- Also of increasing interest at the power system level, including to the Australian Market System Operator (AEMO) given the potential system security impacts of many highly distributed generators.

Distributed PV systems data

- Clean Energy Regulator (CER) collects information of all small PV systems which claim Small-scale Technology Certificates (STC's) under the Small-scale Renewable Energy Scheme (SRES) which includes most of the distributed PV systems
- ARENA has provided this database to the APVI to produce the tools on the APVI Solar Mapping platform
- The APVI publishes a set of customisable charts using this data and updates the results on a quarterly basis



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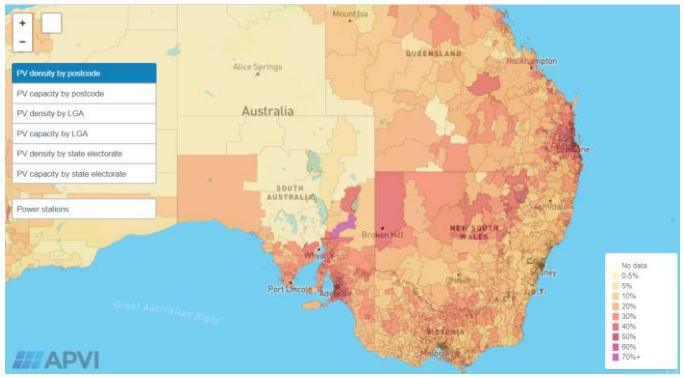
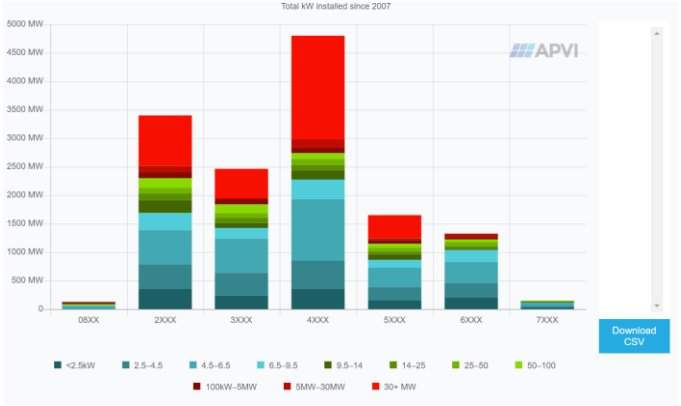
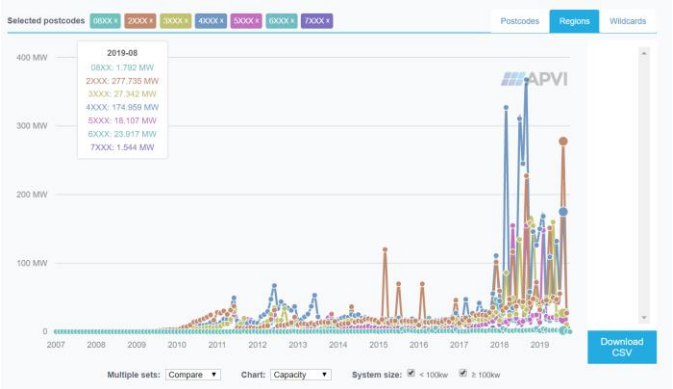
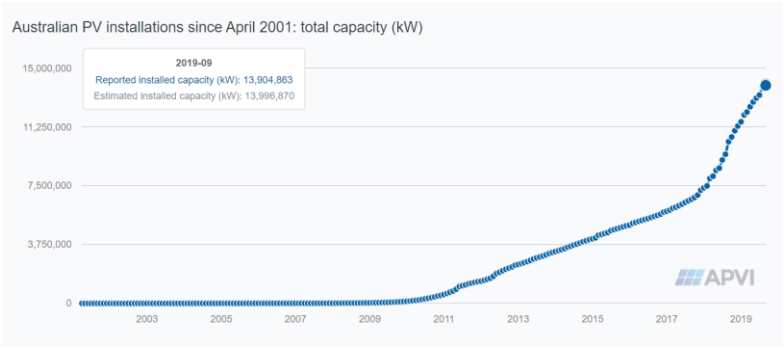
Distributed PV systems data

The charts can be used to view status and monthly trends of capacity and number of PV installations by postcode, LGA or State, broken down by PV (DC) system size category in different pages of the platform at **pv-map.apvi.org.au**





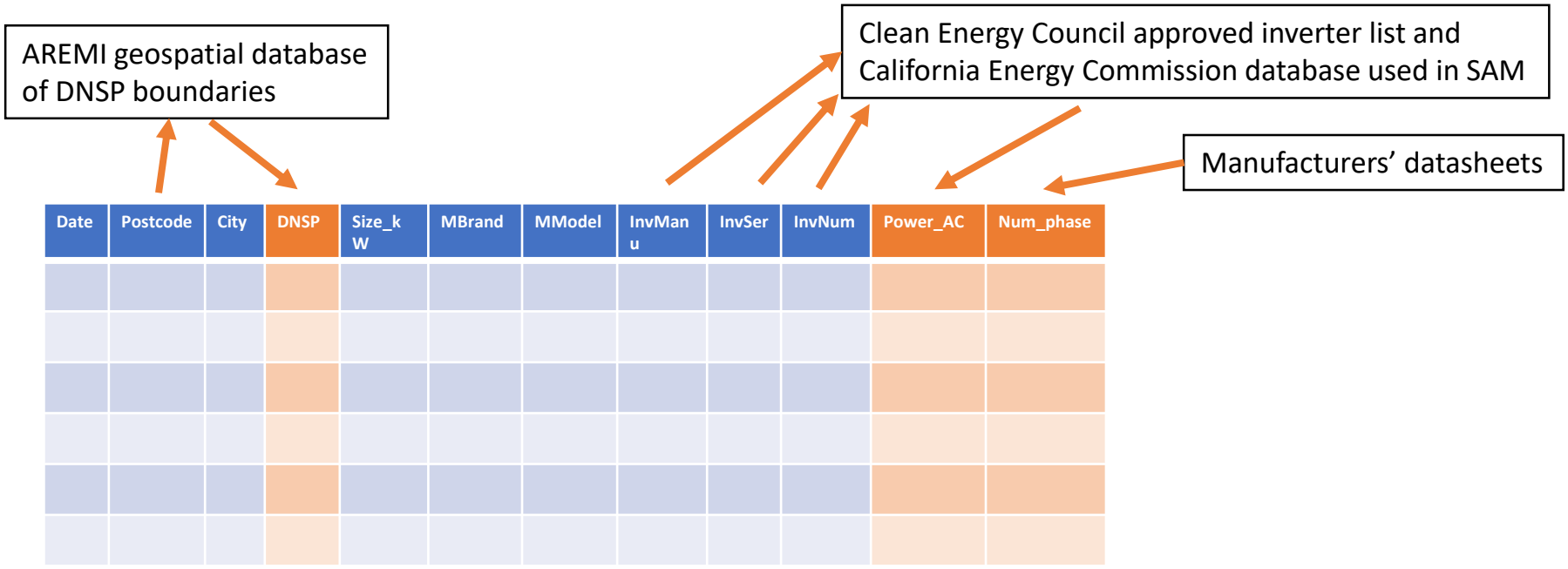




Database matching process

In this study a more detailed analysis was done on the trend of inverters. The data includes:

- System level data from Clean Energy Regulator with postcode, size, module and inverter brand and model and date of installation
- AREMI geospatial data of DNSP boundaries
- Clean Energy Council approved inverter list
- Some inverter manufacturers' datasheets



Data treatment

- Systems installed before mid-2011 (~20% of all fleet) do not all have a record of inverter brand or model and hence were removed
- The data used for this paper was accessed at the end of June 2019, however PV system owners are given 1 year to submit their installation to the CER, and so the data for the first half of 2019 is not complete
- The **California Energy Commission database** used by NREL's System Advisor Model and the Australian **Clean Energy Council** approved inverter list were matched to the database to find the rated power output of inverters for more than 91% of known inverters.

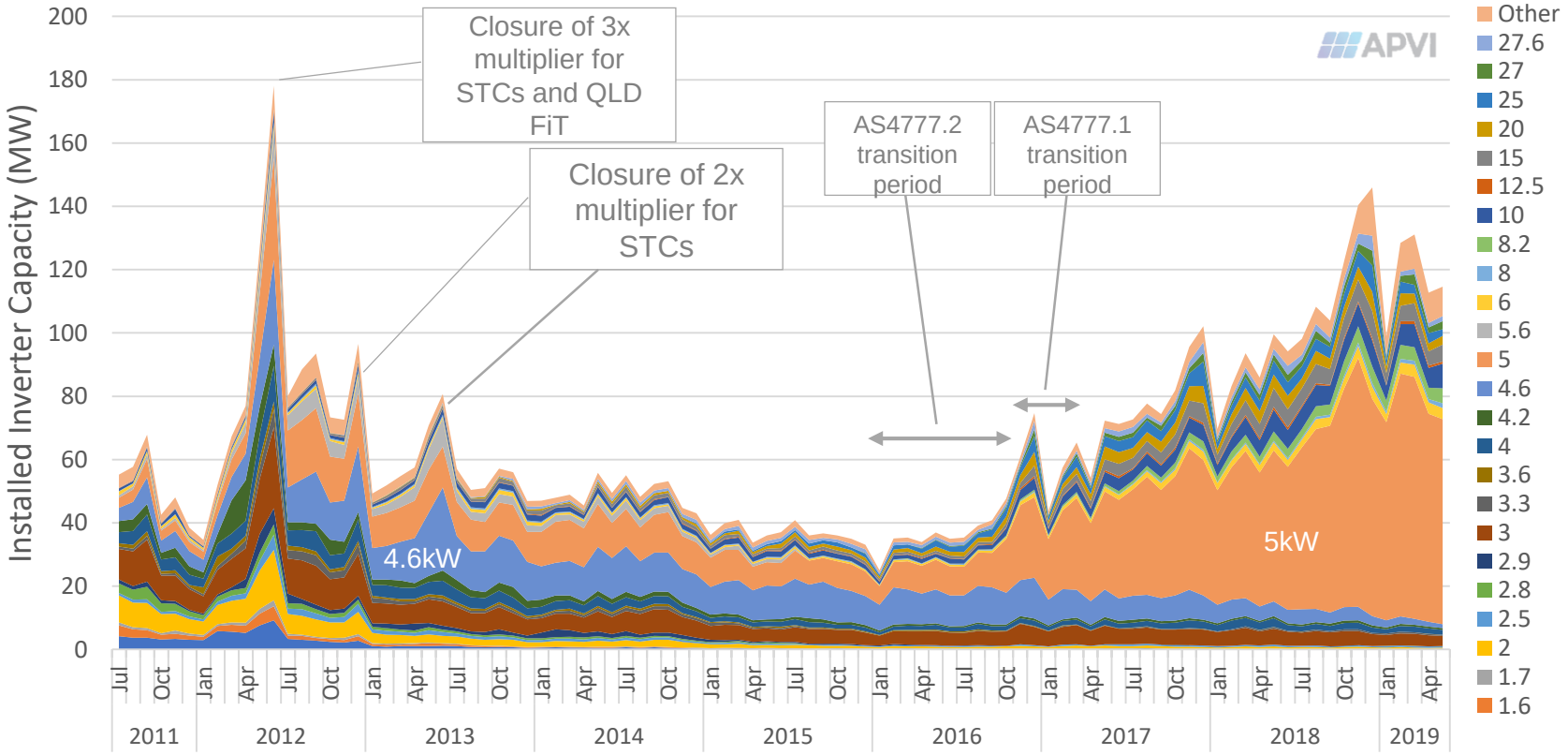
Requirements by different DNSPs

- DNSPs have different requirements for PV systems with some changes over time

State	Company	Historical limits (Noone, 2013)	Date changed	Current limits	Notes and Source document
ACT	ActewAGL	10 kW single phase, 200kW three phase		5 kW single phase	
NSW	AusGrid	10 kW per phase	N/A	10 kVA per phase	Secondary systems requirements for embedded generators (Ausgrid, 2018)
	Endeavour	5 kW single phase, 30 kW three phase	N/A	5 kW single phase, 30 kW three phase	Panels limited to 8 kW for single phase. (Endeavour Energy, 2019)
	Essential Energy	10 kW	July-13	3 kW rural, 5 kW urban single phase	Connecting to the network information pack (Essential, 2019)
NT	Power and Water Corporation	4.5 kW residential, 30 kVA for 3 phase commercial	June-17	5 kVA single phase, 7 kVA three phase	Systems within the given limits may export. Larger systems of up to 10kVA single phase and 30kVA three phase may be installed with a zero-export limit (Power and Water Corporation, 2019)
QLD	Energex	10 kW	May-17	5 kVA single phase, 15 kVA three phase	Connection standard for Micro Embedded Generating Units (0-≤30kVA) (ENERGEX and Ergon Energy, 2017)
	Ergon	5 kW	N/A	5 kVA single phase, 15 kVA three phase	Connection standard for Micro Embedded Generating Units (0-≤30kVA) (ENERGEX and Ergon Energy, 2017)
SA	SA Power Networks	10 kW	Dec-17	10 kW single phase, 30 kW three phase	Export limits set in May-19 to 5kW and 15kW respectively. Technical Standard TS129 (SA Power Networks, 2019)
TAS	TasNetworks	10 kW single phase, 30 kW three phase	N/A	10 kW single phase, 30 kW three phase	Requirements for Connecting Micro Embedded Generating Systems to the TasNetworks Distribution Network (TasNetworks, 2017)
VIC	AusNet	4.6 kW single phase, 5 kW three phase		10 kW per phase	Export limited to 5kW per phase (AusNet Services, 2019)
	CitiPower	10 kW per phase		5 kW single phase, 30 kW three phase	CitiPower & Powercor website (CitiPower and Powercor Australia, 2019)
	Jemena	10 kW per phase	N/A	10 kW single phase, 30 kW three phase	Jemena website (Jemena, 2019)
	United Energy	10 kVA per phase	N/A	10 kW single phase, 30 kW three phase	UE Embedded generation network access standards (United Energy, 2017)
WA	Horizon Power	10 kW per phase	N/A	10 kVA single phase, 30 kVA three phase	Horizon Power website (Horizon Power, 2019)
	Western Power	5 kVA single phase, 30 kVA three phase		10 kW single phase, 30 kW three phase	Network Integration Guideline for Inverter Embedded Generation (Western Power, 2019)

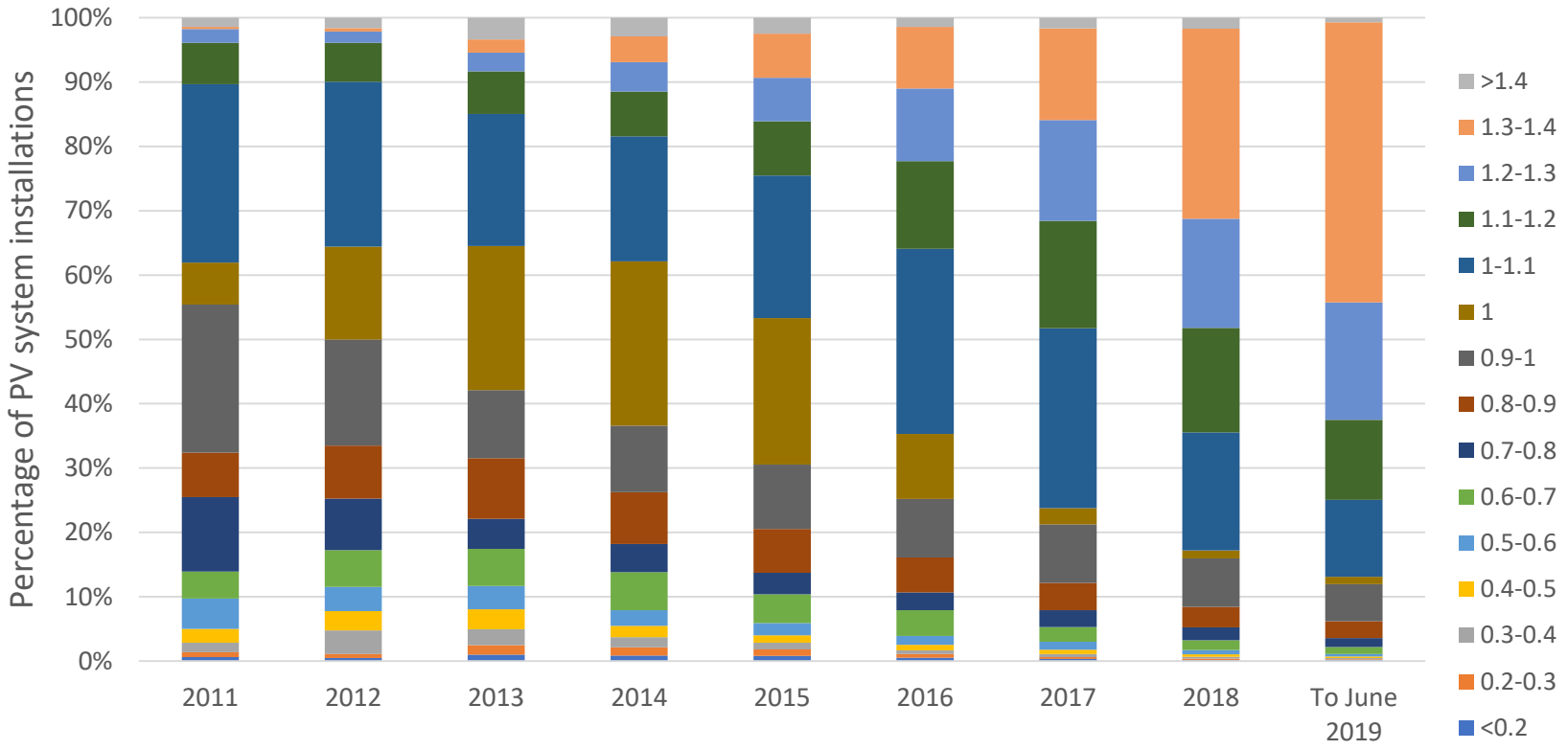
Trends in inverter rated capacity

- As the price of PV panels and balance of systems components has fallen, there has been a shift towards installations with a higher AC output.
- However, this is bounded by AC inverter limits set by distribution network businesses, and inverters rated at 5kW now command the largest market share.



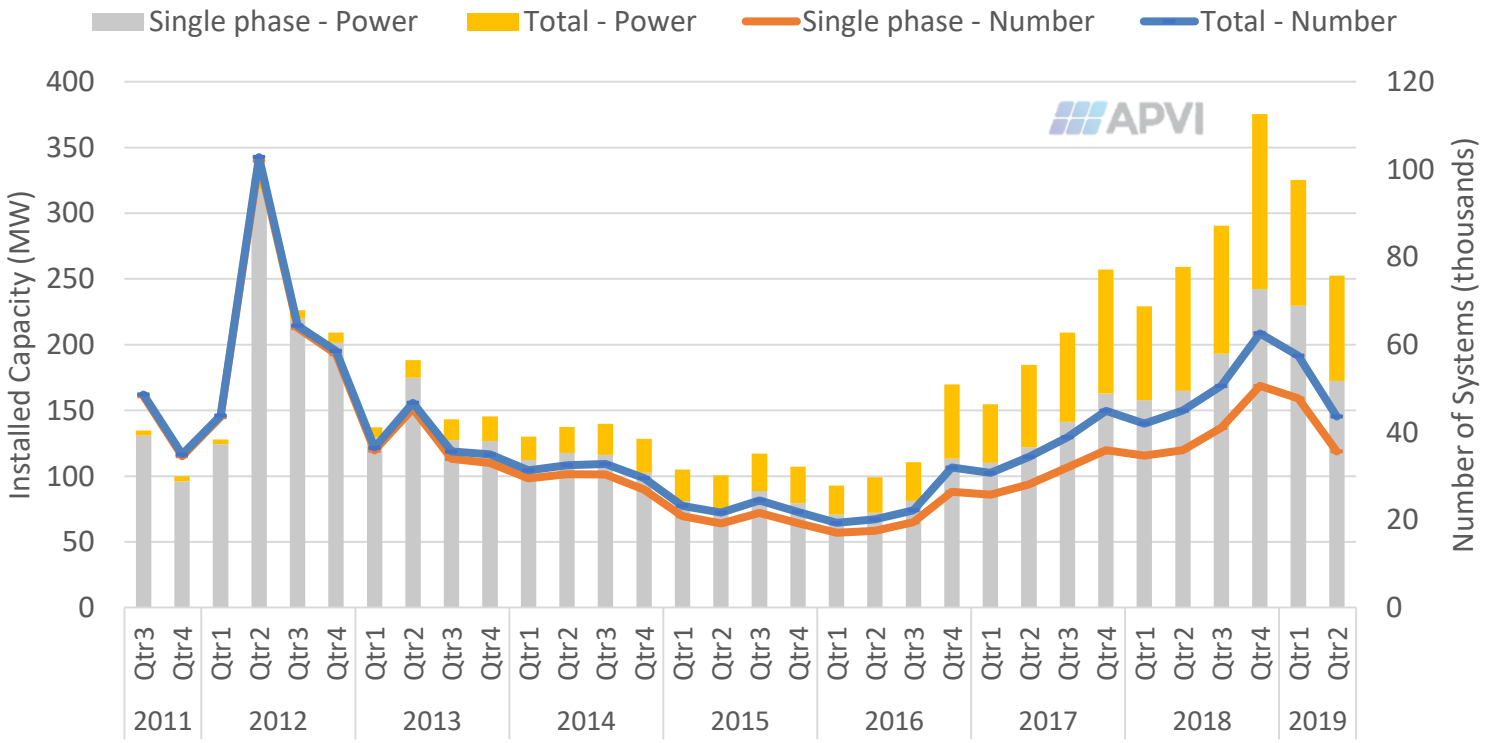
DC to AC ratio

- DC to AC ratio has changed dramatically due to the significant price drop for PV modules and limit in the AC size introduced in standards and requirements by DNSPs



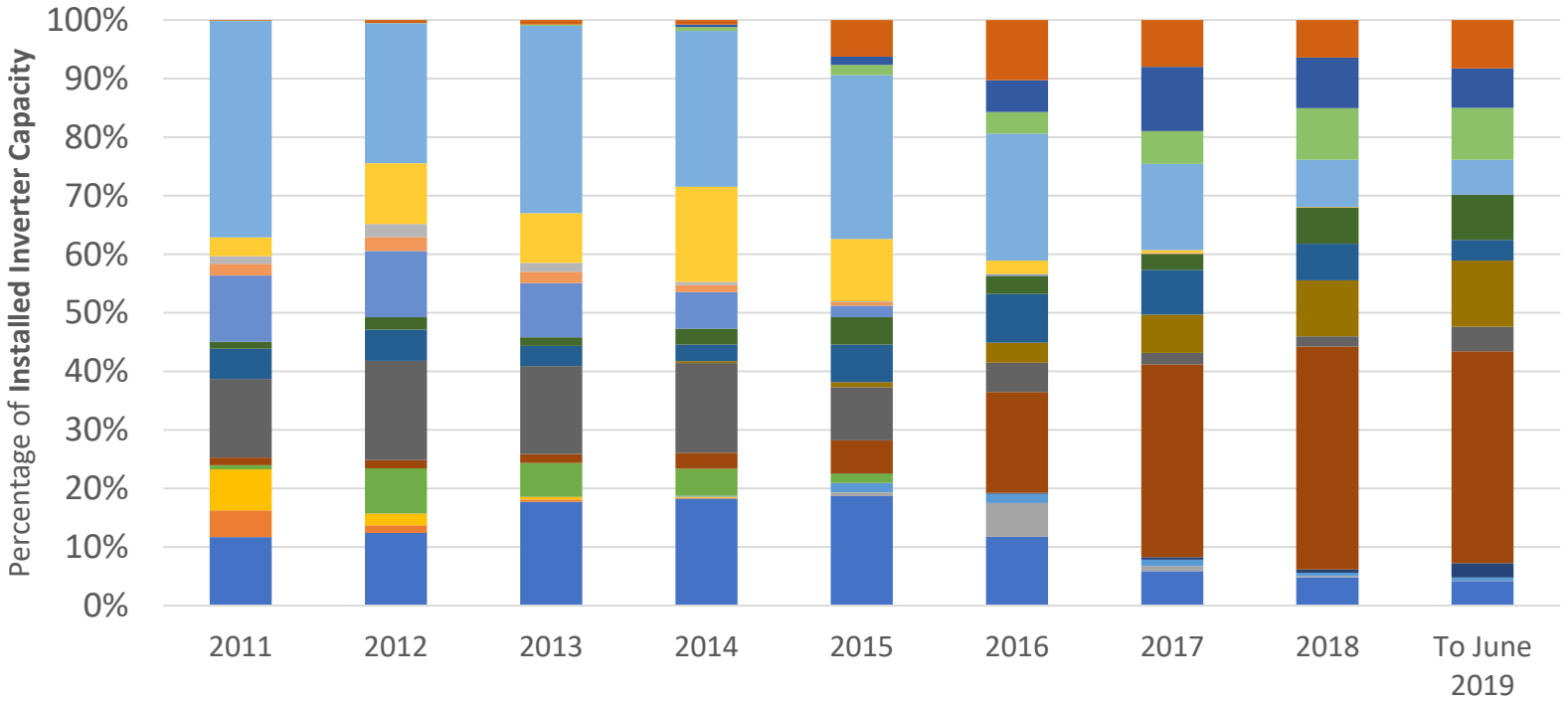
Number of phases

- The number of connection phases for most inverters in the database was determined from the manufacturers' datasheets.
- Many DNSPs have the rule of maximum 5kW per phase, so larger systems tend to be three phases



Market share

- There has been considerable development of the market for distributed PV inverters in Australia and internationally over the last 9 years, including changes in product requirements according to standards and consumer demand
- These figures show inverter market held by each of the most popular **20** companies, quantified by **installed capacity** and **number of inverters** installed respectively



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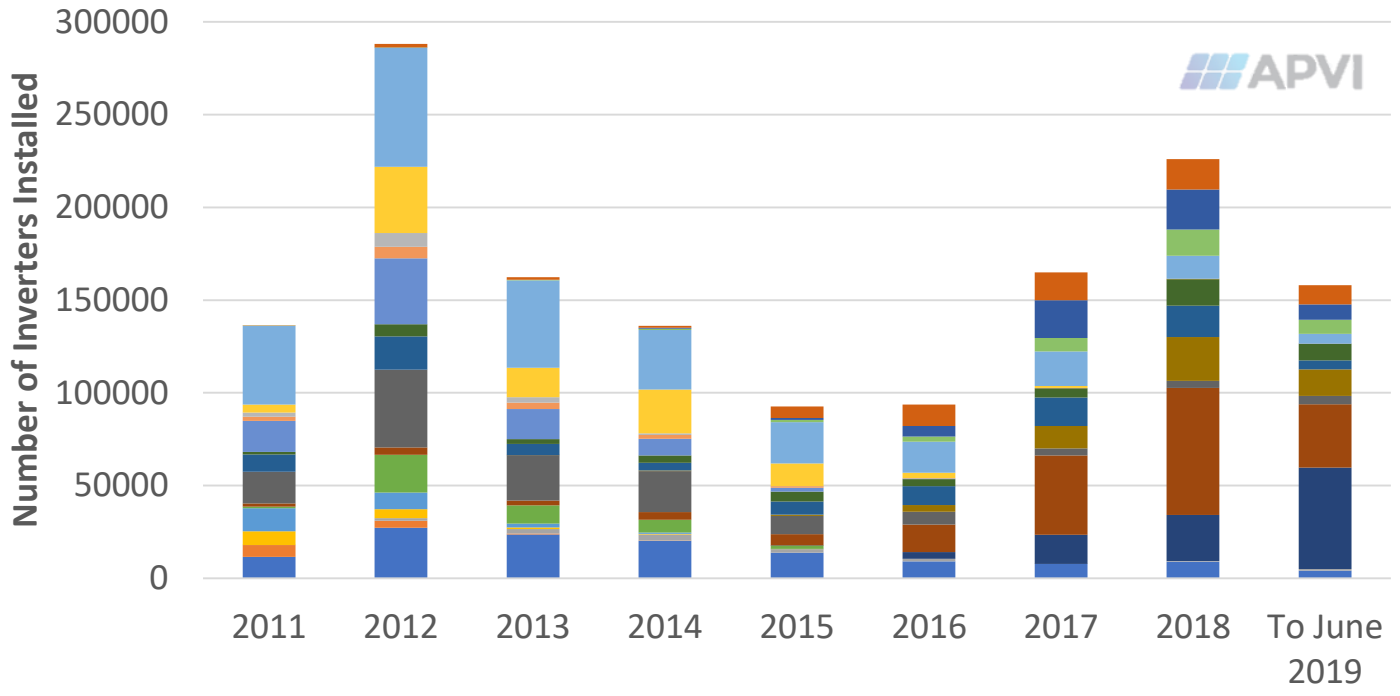
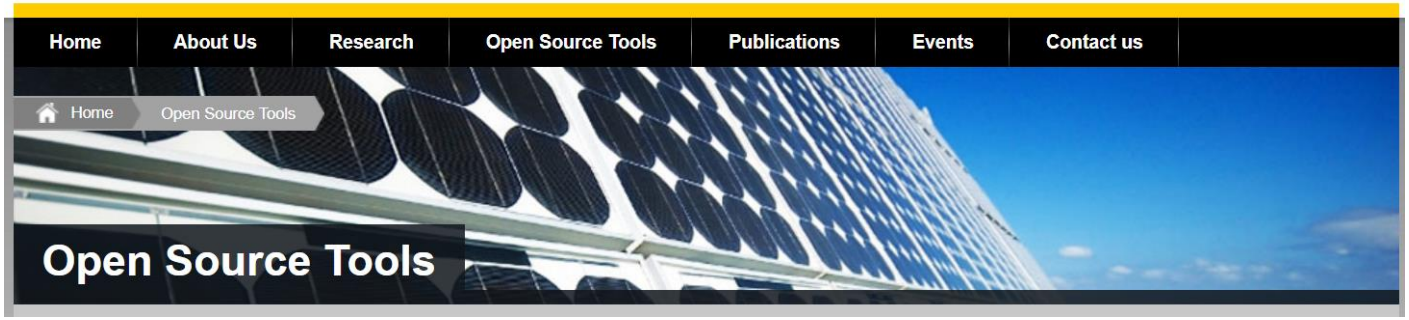


Discussion and implications

- **Inverter rated capacity -** larger systems means higher potential export and hence higher voltage which may result in increased PV tripping or operation of the V-W and V-Var response modes.
- **Higher DC to AC ratio** – is expected to increase clipping and change the overall PV generation profile shape which is important to appreciate when modelling distributed PV contribution
- **Single vs Three phase systems** – the prevalence of three phase systems may provide better voltage management capability but also changes the response of distributed PV systems to power system events
- **Inverter brand –** different brands can have different operational characteristics under normal conditions and in response to system disturbances, so understanding the market share is increasingly important

Remarks

- Check out CEEM's website http://ceem.unsw.edu.au/



Q&A

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