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Assessing the Economic Value and Market Implications of PV in the Australian National Electric Market

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Value of Solar PV for Singapore

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Economic value and market implications

- Economic Value
  - Values (plural) the moral principles and beliefs or accepted standards of a person or social group
  - the desirability of a thing, often in respect of some property such as usefulness or exchangeability; worth, merit, or importance
  - **an amount, especially a material or monetary one, considered to be a fair exchange in return for a thing; reasonable or equivalent return; satisfaction" ⇒ value for money“**
- Market value
  - An amount considered to be a fair exchange in return for a thing **between parties transacting** through market arrangements
- *Ideally, good alignment b/n economic and market value In practice, often challenging given economic uncertainties, market realities; certainly challenging in electricity industry*

Value of PV within an electricity industry

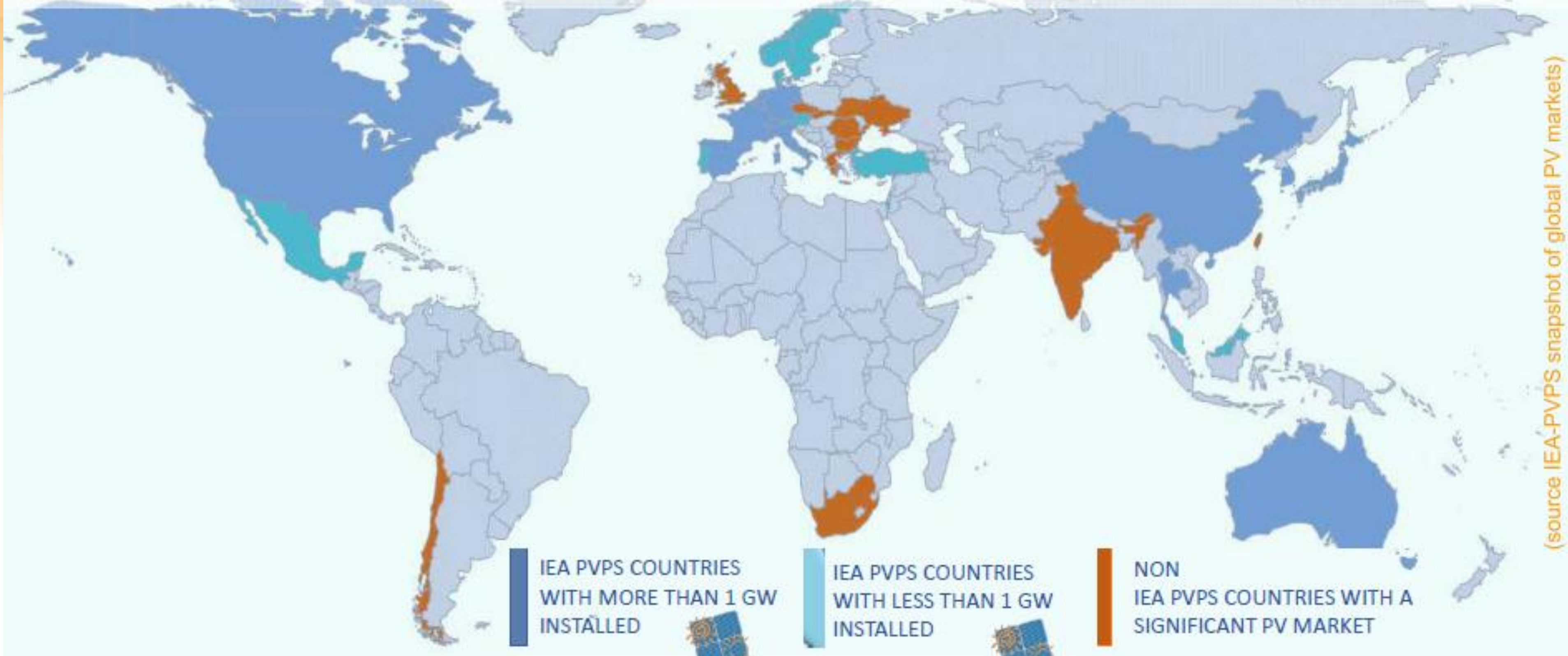
- Electricity industry economics complex
  - Value derives from **flows of desired energy services** to diverse consumers, requiring **timely** delivery of power of acceptable quality, to **where** needed through **asset intensive** dedicated network and generation infrastructure, with major env. and social **externalities**, positive and negative, *in dynamic, only partially predictable context*
- Electricity ‘designer’ market arrangements
  - also inherently complex and incomplete in matching economics with commercial ‘signals’ to market participants
- PV economics complex
  - Highly capital intensive cost assets with a complex **supply chain**, highly variable and somewhat **unpredictable operating** characteristics, very scalable hence wide range of **locational** and potential stakeholder opportunities, **low environmental impacts**
- *PV a poor, fit with current electricity market arrangements*

PV's economic value hence depends on…

- how much PV
  - assessment on margin only goes so far, high penetrations harder
- sourced through what supply chain
  - both commodity and service stages, quality can vary greatly
- installed in what manner and where
  - including orientation and tilt, quality of site selection and installation
  - location dependent performance, potential network costs or benefits
- and then how operated
  - opportunities to cause or help address operational challenges
- in what particular electricity industry context
  - climate, nature of demand, other generation sources and options
- and with respect to which broader societal objectives
  - including economic development, social and environmental outcomes

PV has now arrived – growth trend worldwide

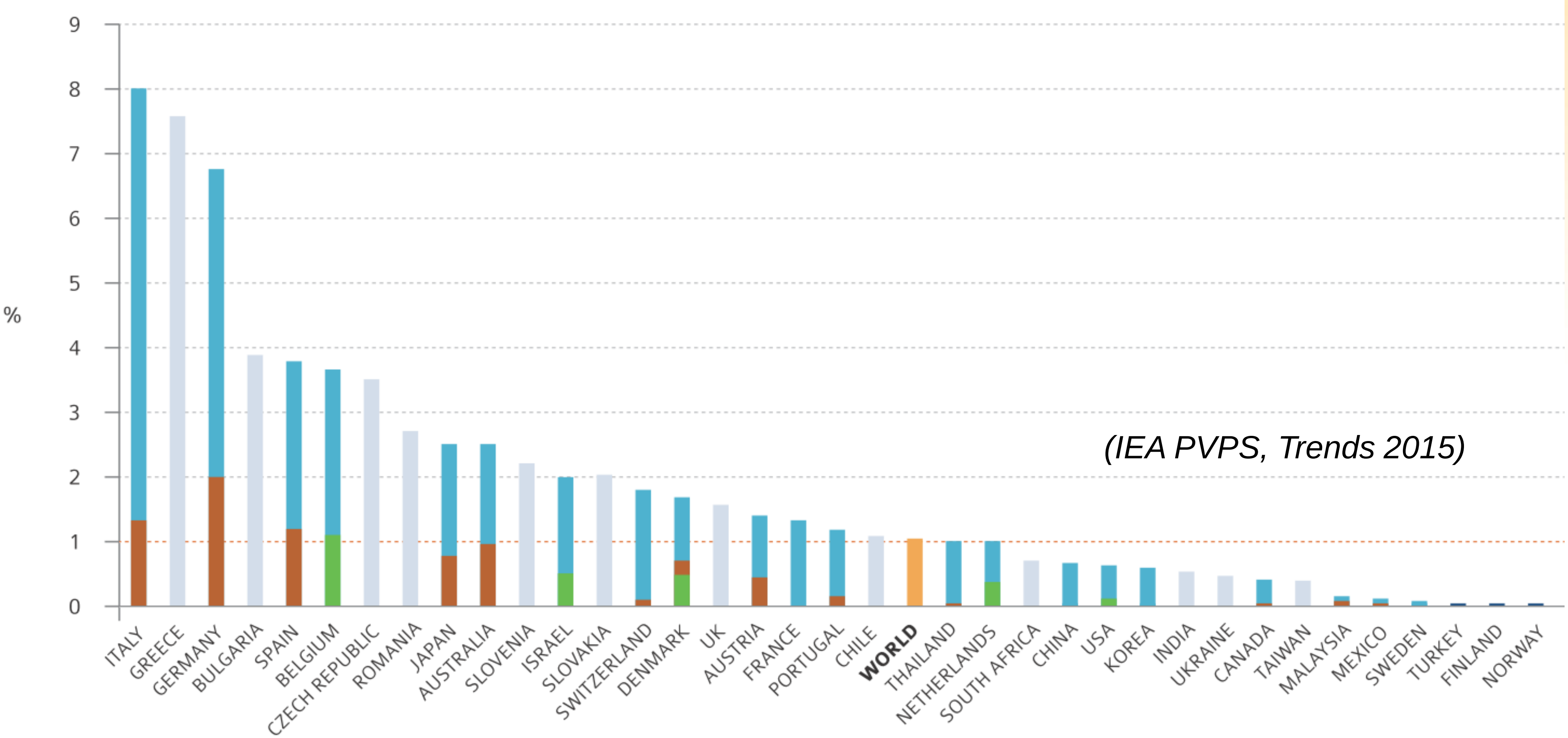
- 177 GW installed worldwide at the end of 2014
- PV penetration levels growing worldwide (+38.7 GW in 2014)
- 20 countries with installed PV capacity of more than 1 GW



(Brundinger, Task 14 Update, 2015)

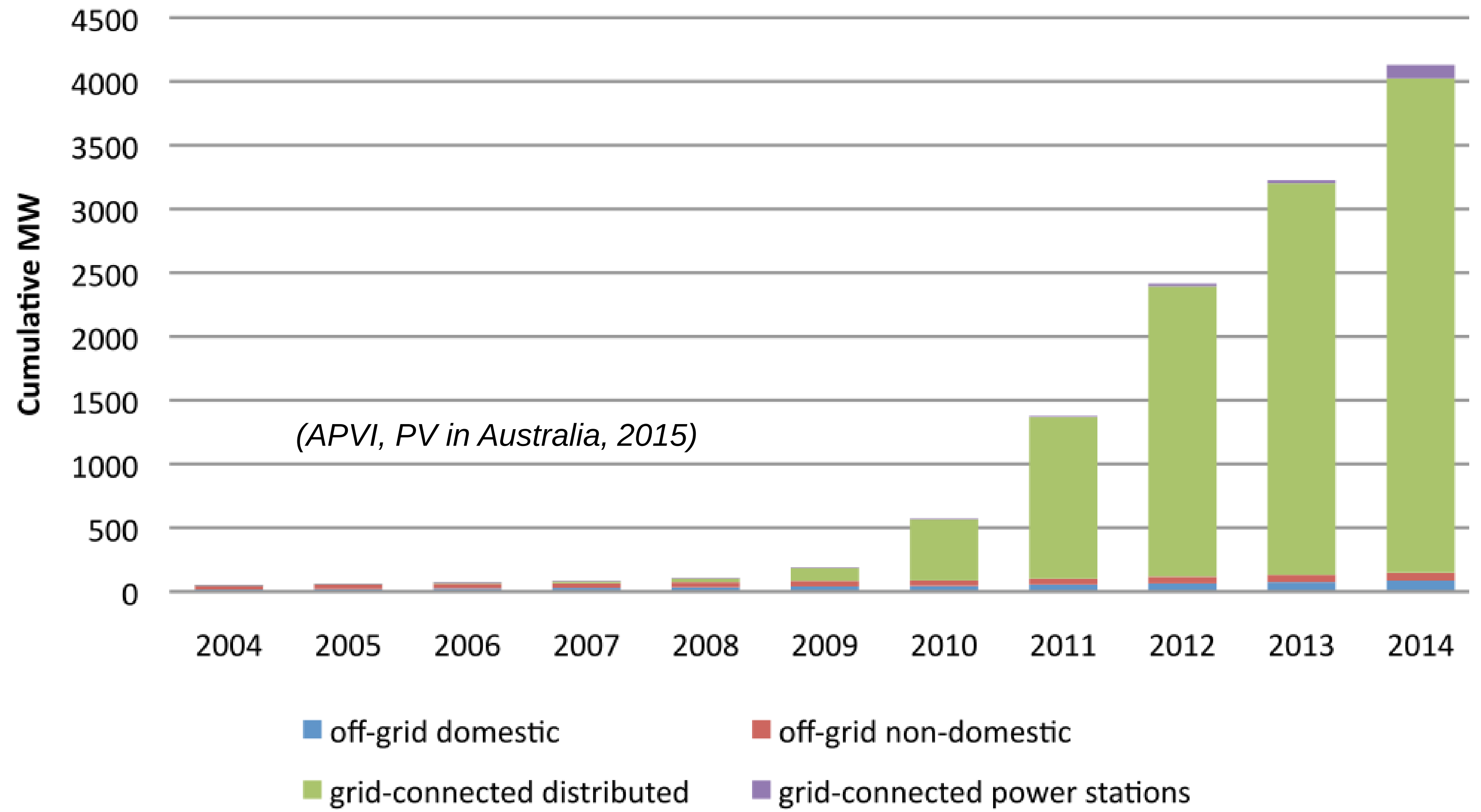
Australian PV penetration significant

FIGURE 22: PV CONTRIBUTION TO THE ELECTRICITY DEMAND IN 2014

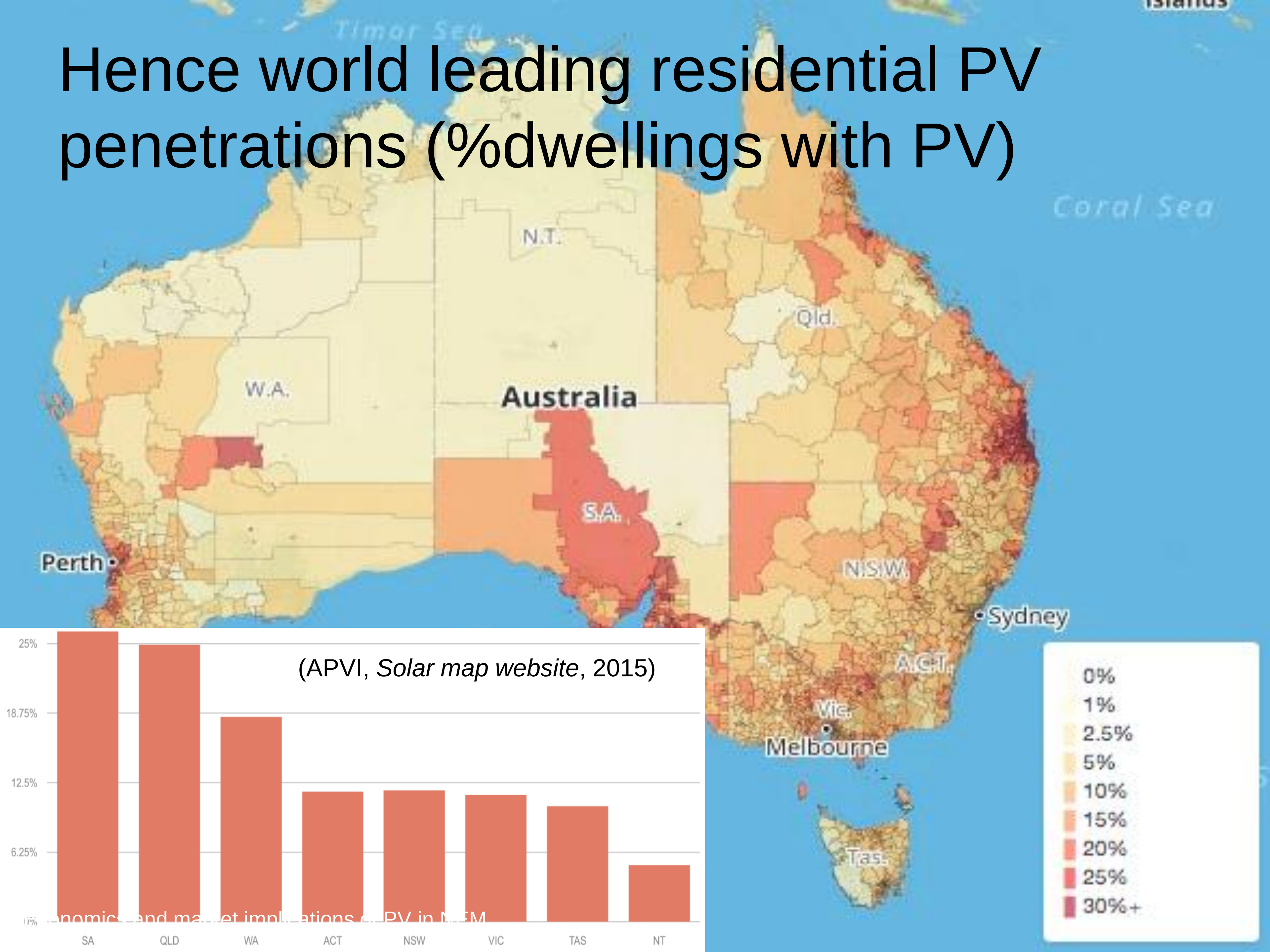


…. and largely a household story to date

…although commercial and utility scale PV now growing fast



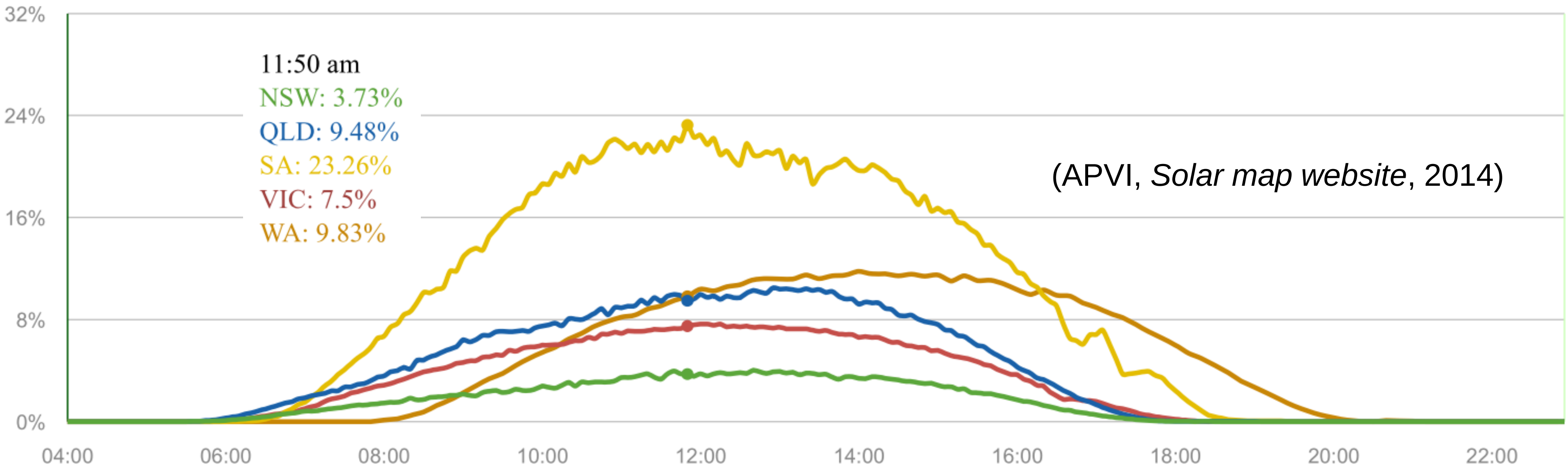
Hence world leading residential PV penetrations (%dwellings with PV)



(APVI, *Solar map website*, 2015)

PV penetrations now having industry-wide impacts in some States, particularly SA

(eg. Estimate of PV contribution to electricity demand by State, 5 October 2014)

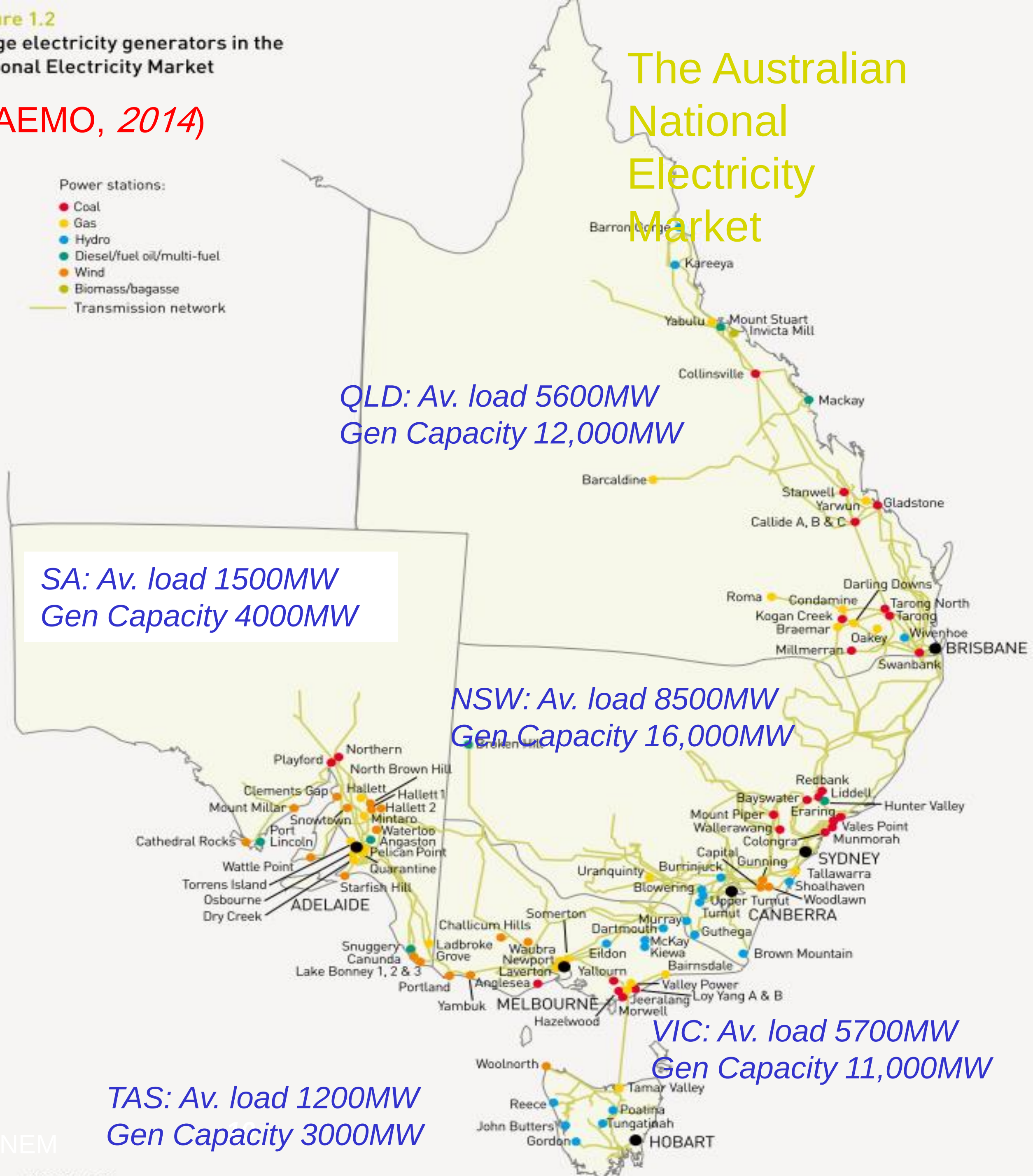


Australian National Electricity Market

Figure 1.2
Large electricity generators in the National Electricity Market

(AEMO, *2014*)

The Australian National Electricity Market



QLD: Av. load 5600MW
Gen Capacity 12,000MW

SA: Av. load 1500MW
Gen Capacity 4000MW

NSW: Av. load 8500MW
Gen Capacity 16,000MW

VIC: Av. load 5700MW
Gen Capacity 11,000MW

TAS: Av. load 1200MW
Gen Capacity 3000MW

Sources: AEMO; AER

PV supply chain, deployed costs in Australia

- Now only very limited module and BOS manufacturing
- Relatively low-cost residential installation costs by world-wide standards

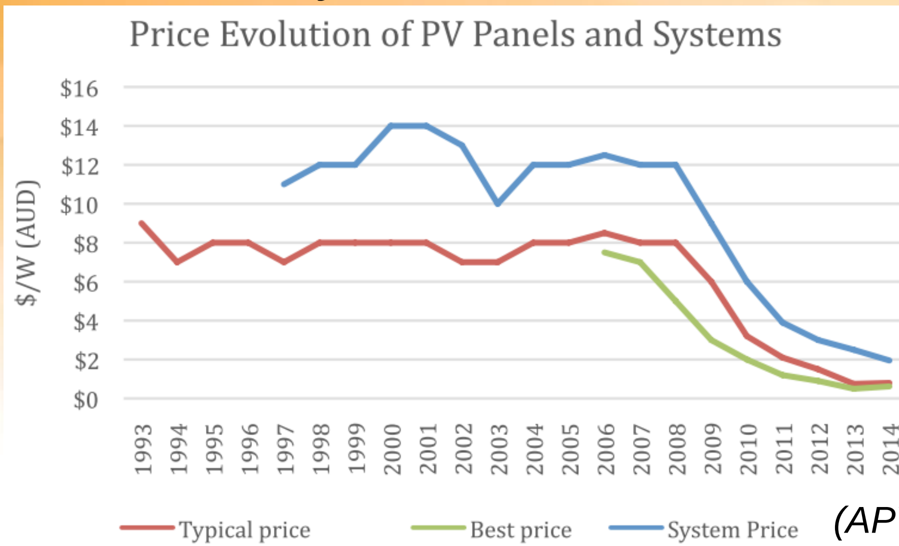


Table 8: Cost breakdown for a residential PV system – Australian Dollars (AUD)

Cost category	Average (AUD/W)
Module	0,77
Inverter	0,33
Other (racking, wiring)	0,21
Installation	0,35
Customer Acquisition	0,08
Profit	0,36
Other (permitting, contracting, financing)	0,04
Subtotal Hardware	**1,31**
Subtotal Soft costs	**0,83**
Total	**2,14**

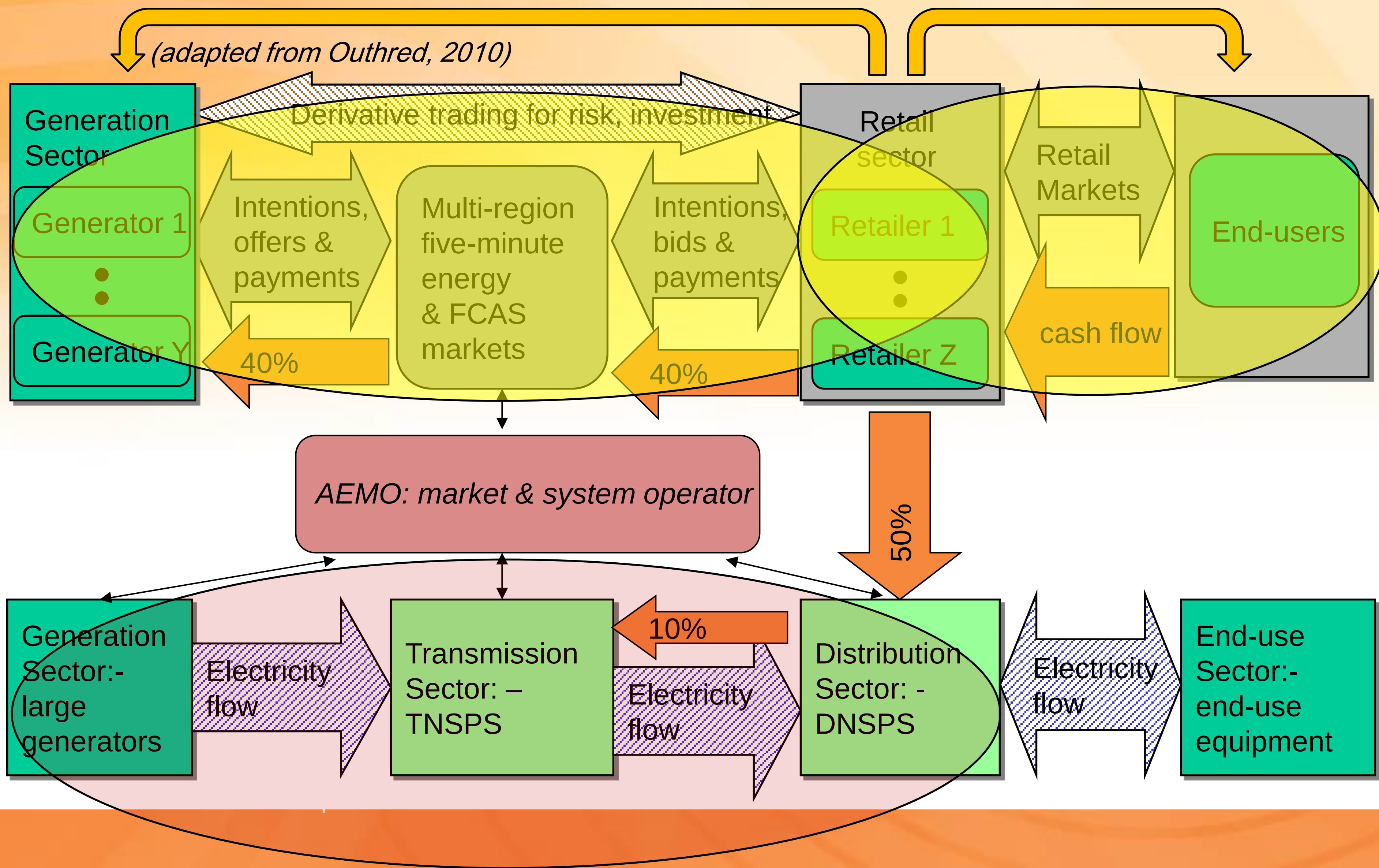
(APVI, PV in Australia, 2015)

Category/Size	Typical applications and brief details	Current prices per W
OFF-GRID Up to 1 kW	Water pumps, lighting, remote homes	AUD 9 - AUD 15
OFF-GRID >1 kW	Pastoral systems	AUD 7,50/W – AUD 11/W
	Telecommunications / mining power systems	AUD 22/W – AUD 60+/W
Grid-connected Rooftop up to 10 kW (residential)	Residential	AUD 1,95
Grid-connected Rooftop from 10 to 250 kW (commercial)	Commercial rooftop	AUD 1,78
Grid-connected Rooftop above 250 kW (industrial)	Larger rooftops	AUD 1,80
Grid-connected Ground-mounted above 1 MW	Solar farms	AUD 1,80

Table 16: Estimated PV-related labour places in 2014

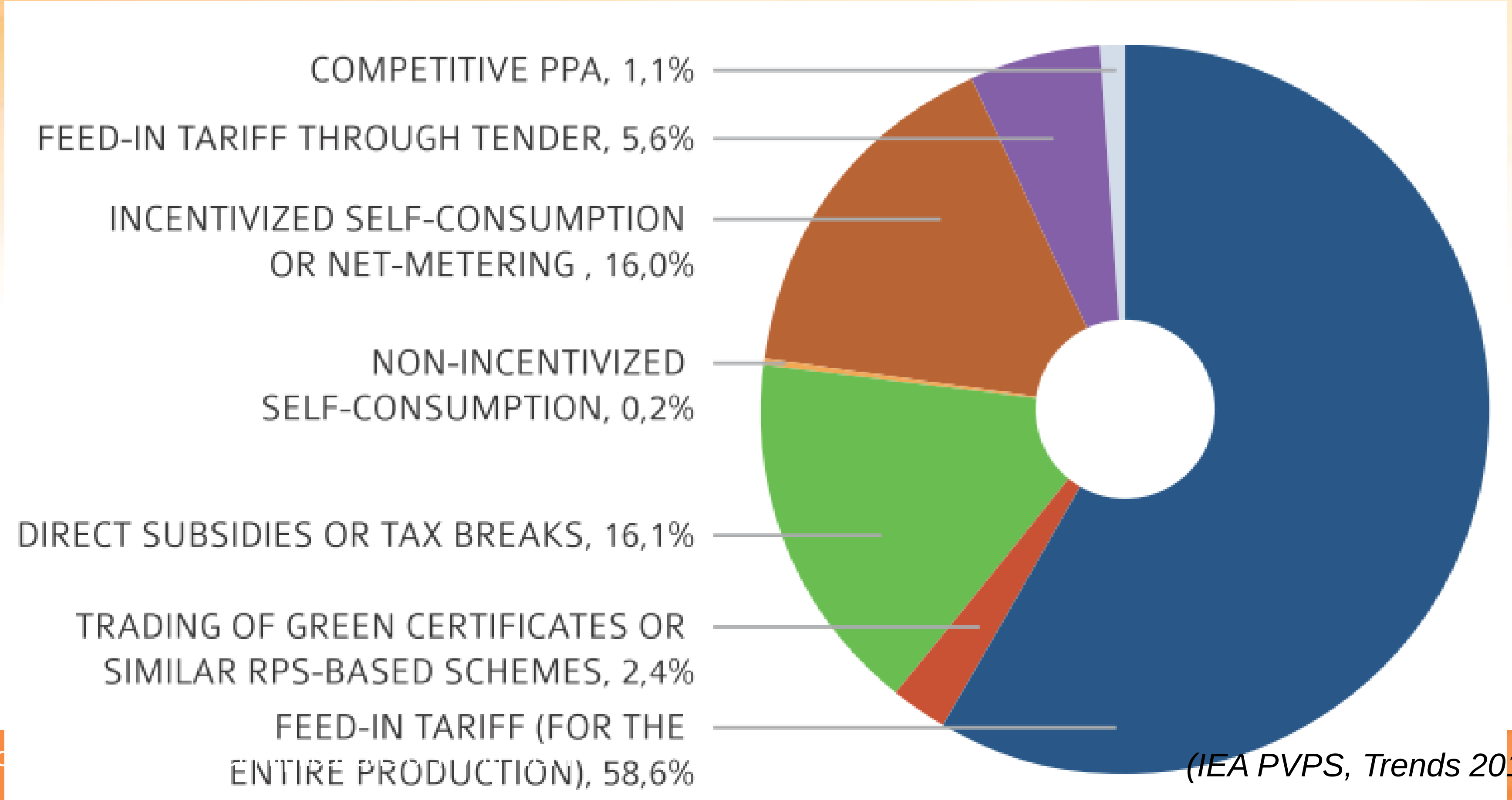
Research and development (not including companies)	400
Manufacturing of products throughout the PV value chain from feedstock to systems, including company R&D	20
Distributors of PV products	200
System and installation companies	10.500
Electricity utility businesses and government	500
Other	3.000
Total	14.620

Australian NEM – regulatory, commercial regimes



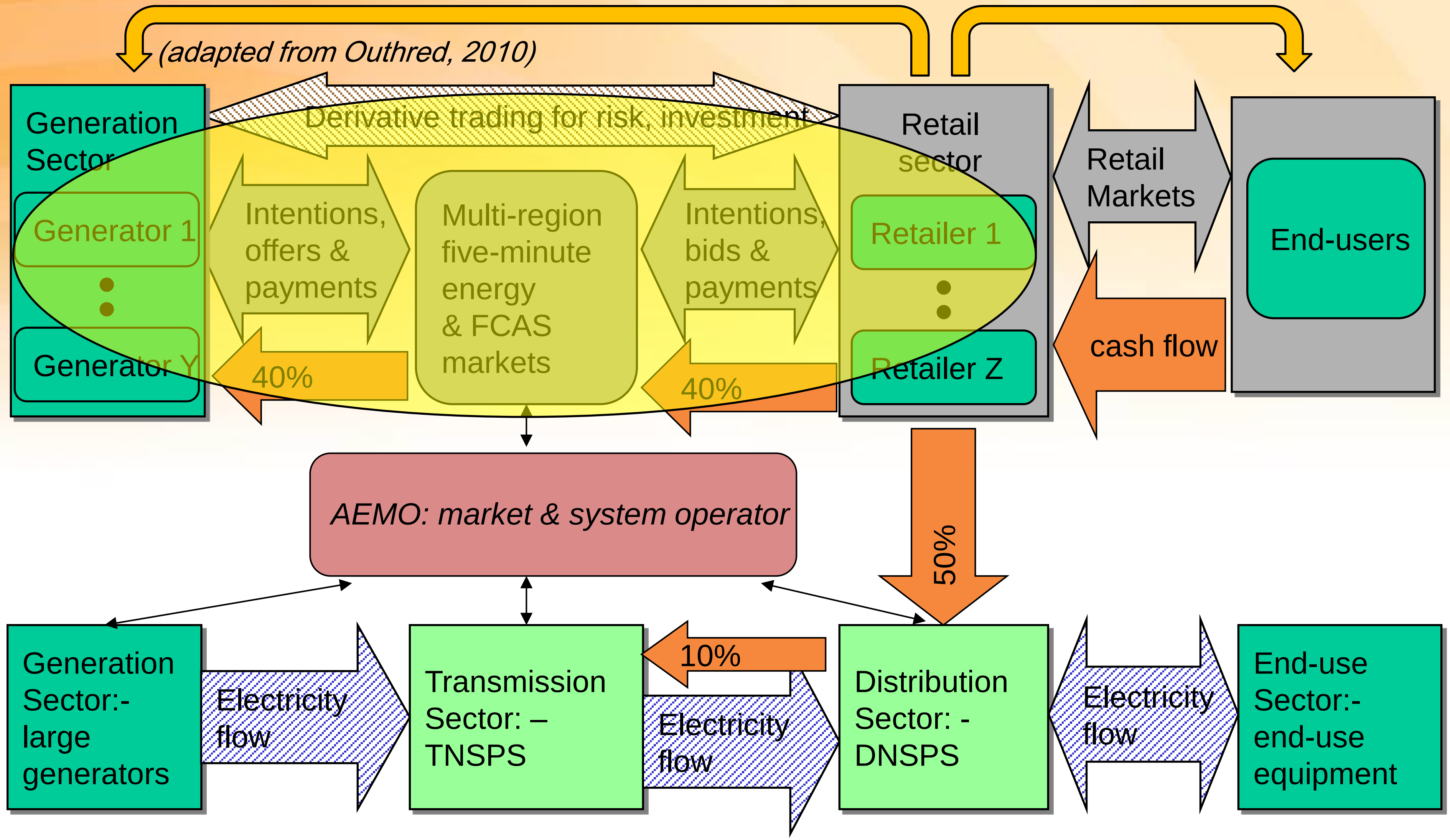
Range of PV relevant market frameworks – specific PV support, broader energy markets

… Australia has tried pretty much all mechanisms at some time, at some or other jurisdictional level; now RPS / Green Certificates



(IEA PVPS, Trends 2015)

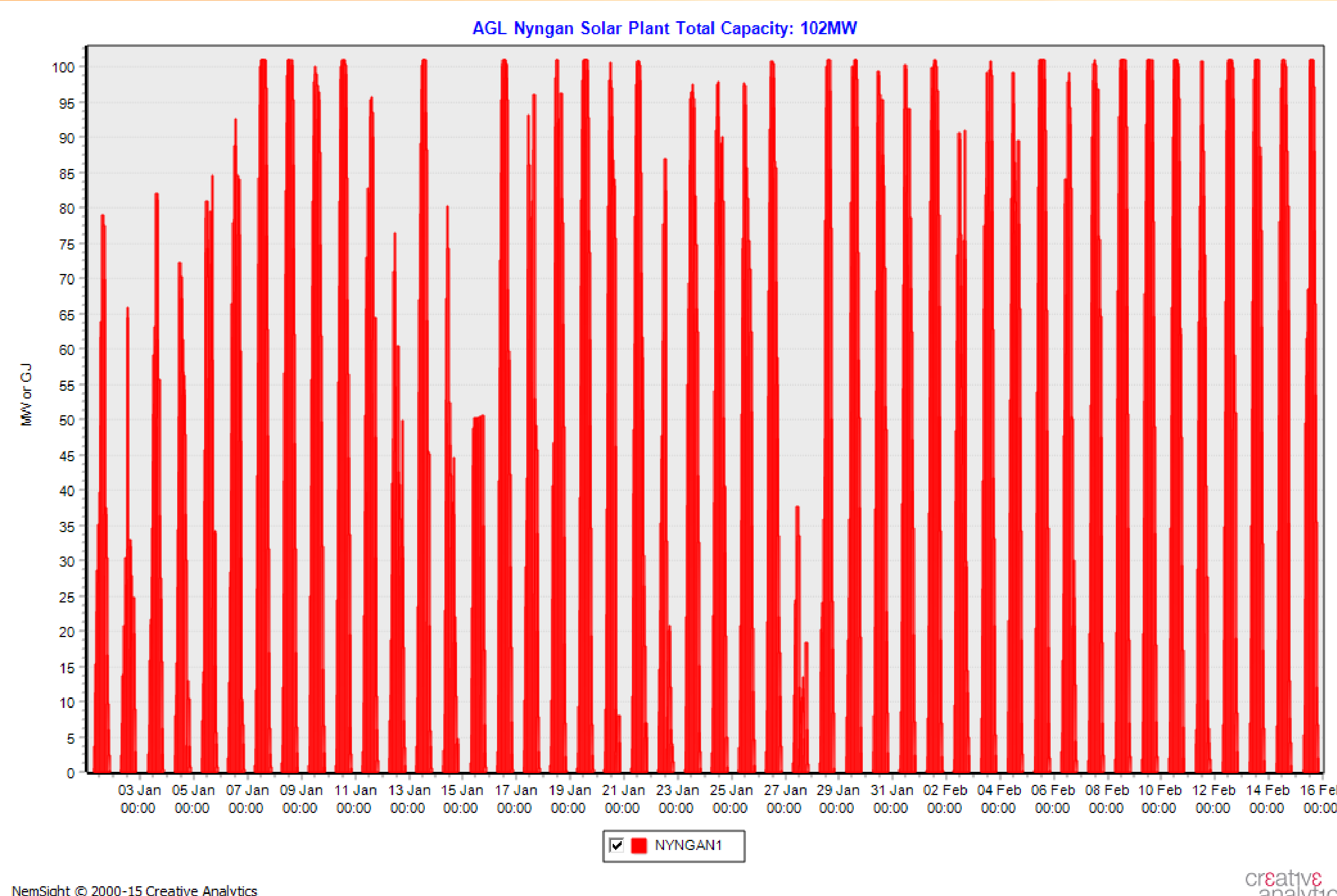
Australian NEM – regulatory, commercial regimes



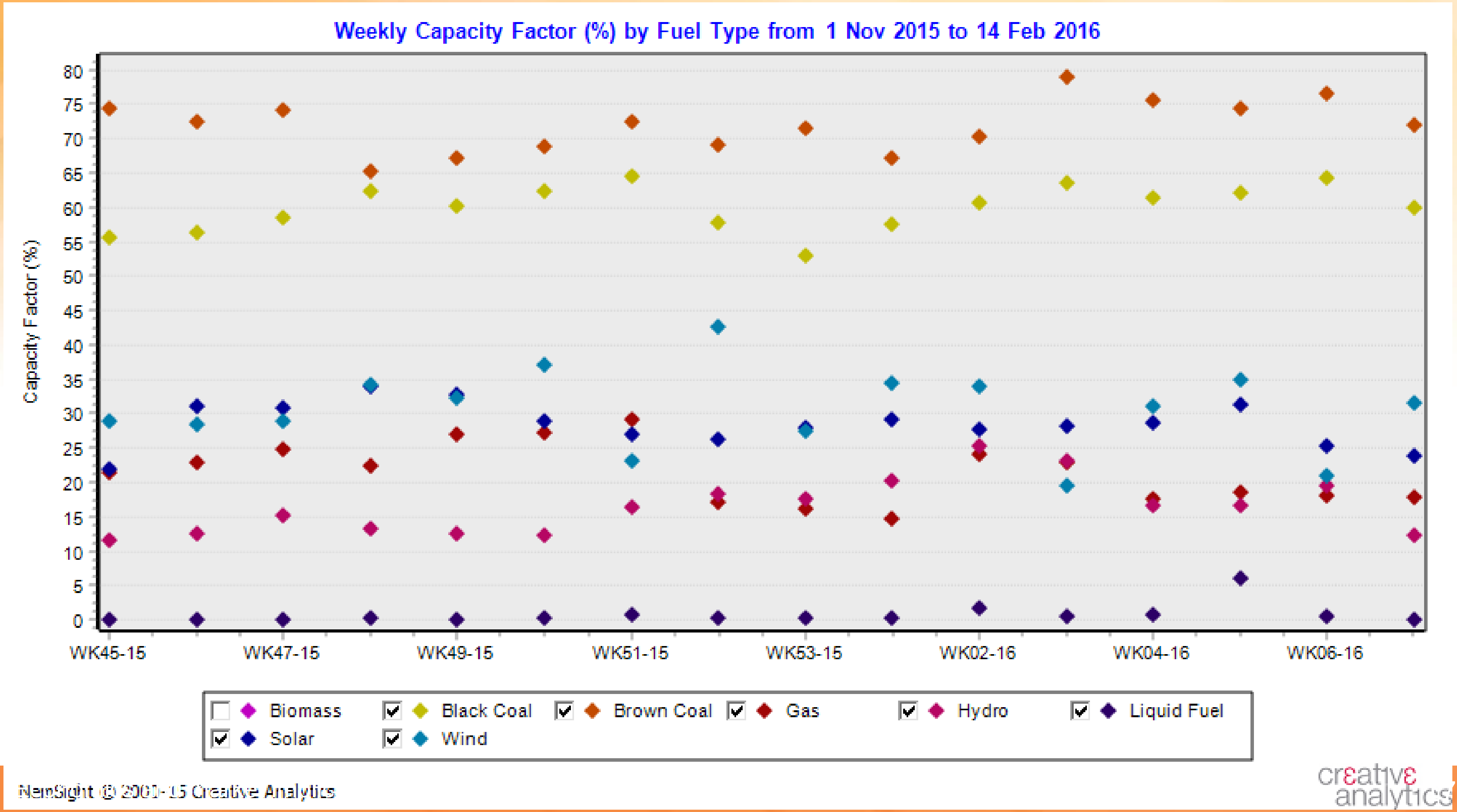
Utility PV value and market arrangements

- Energy
  - Wholesale spot price varies over time depending on changing supply and demand conditions, and uncertainties in these
  - Dynamic spot price over 5 regions, average annual loss factors applied for intra-regional Tx networks
  - Future pricing through a range of derivative markets
  - *Utility PV required to participate in scheduling and spot market, generally financed through derivative based PPAs*
- Ancillary services (short-term frequency, voltage control)
  - Eight FCAS markets for regulation and contingencies, tendered NCAS with some efforts towards causer pays for both demand, generation
- Environmental
  - No carbon price or other direct wholesale market intervention PV generally offsetting gas or coal generation on margin
  - Utility PV support through separate RET market for ‘new’ RE gen

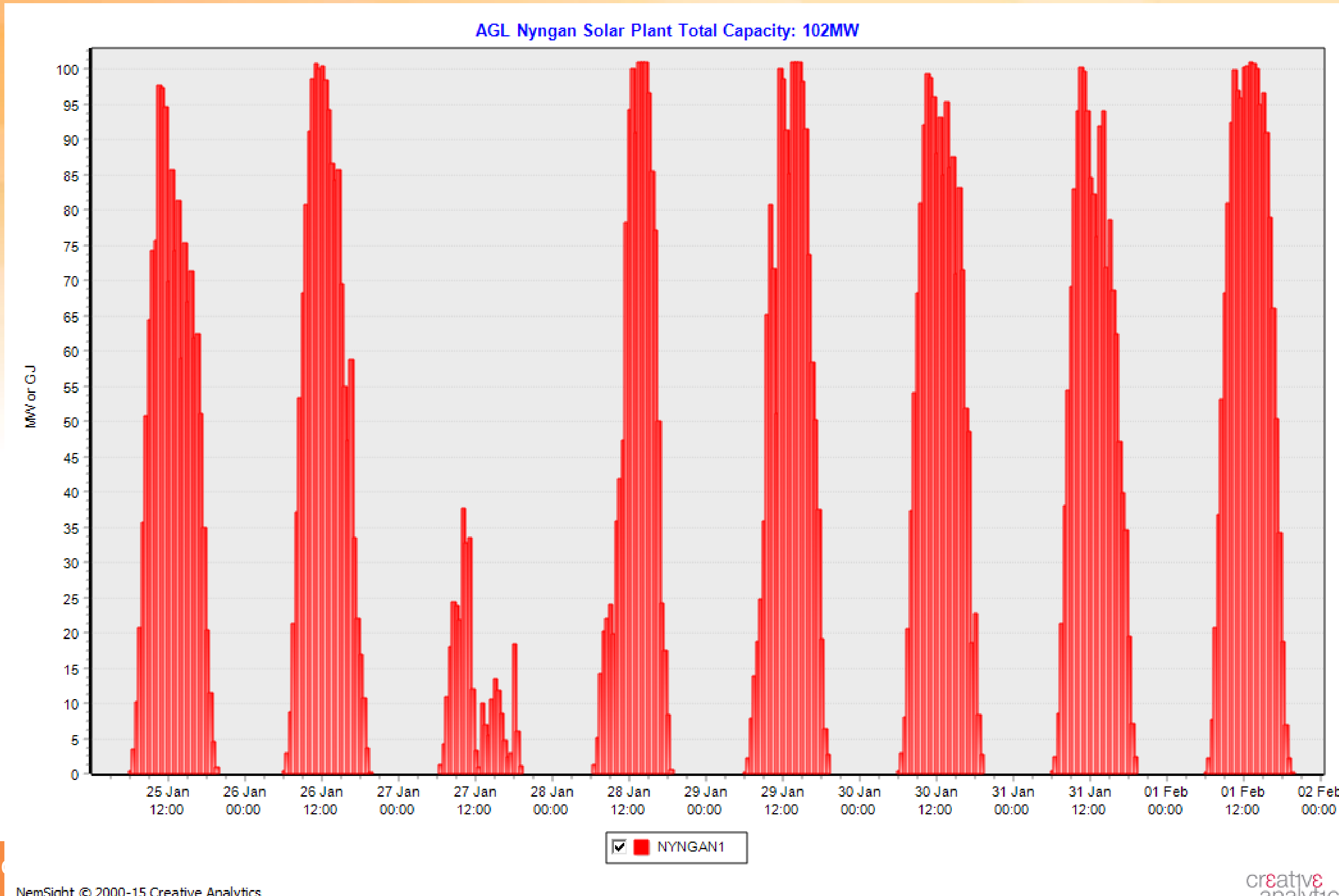
Operation of NEM's largest utility PV plant



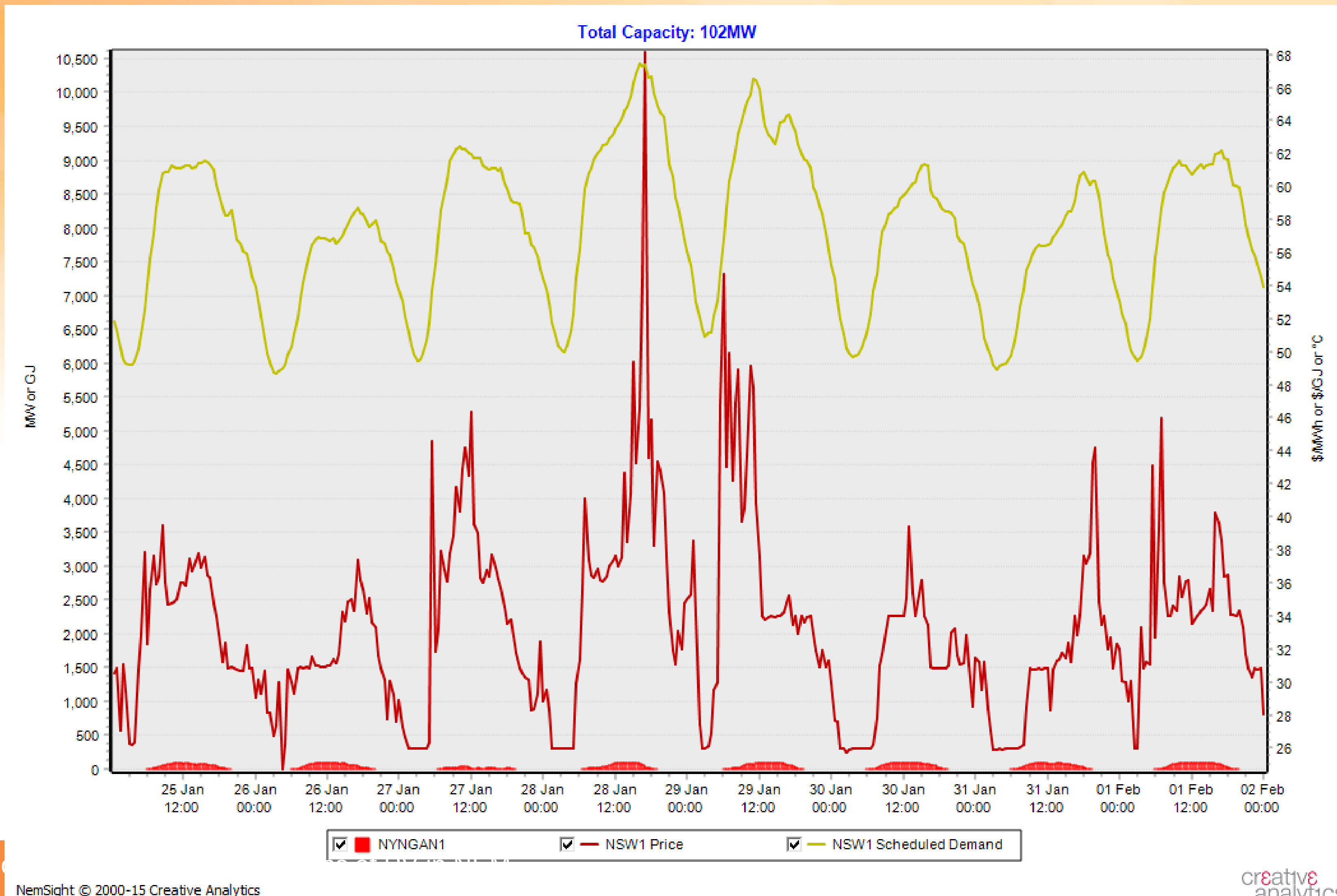
Variable but reasonable capacity factor



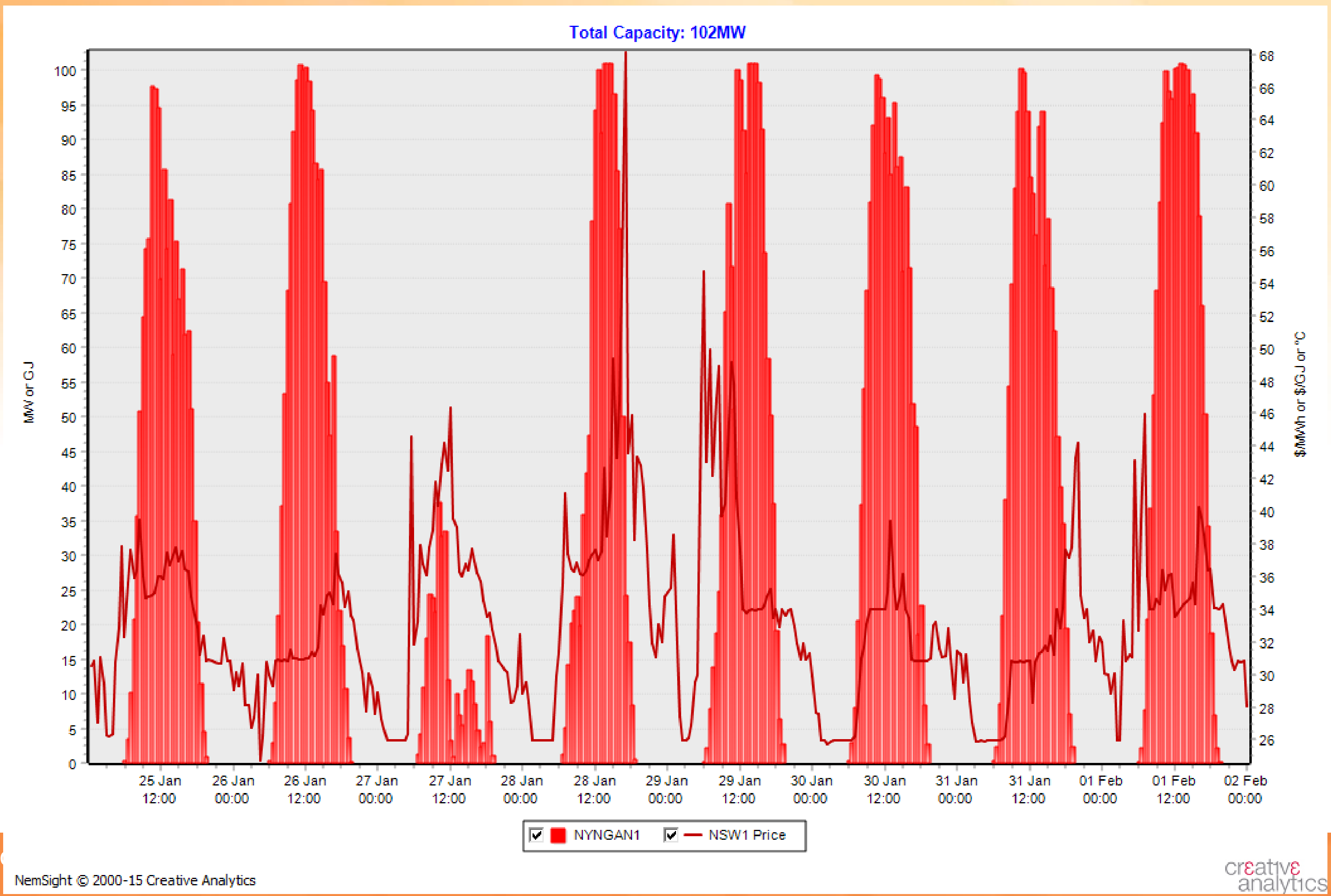
… a variable week



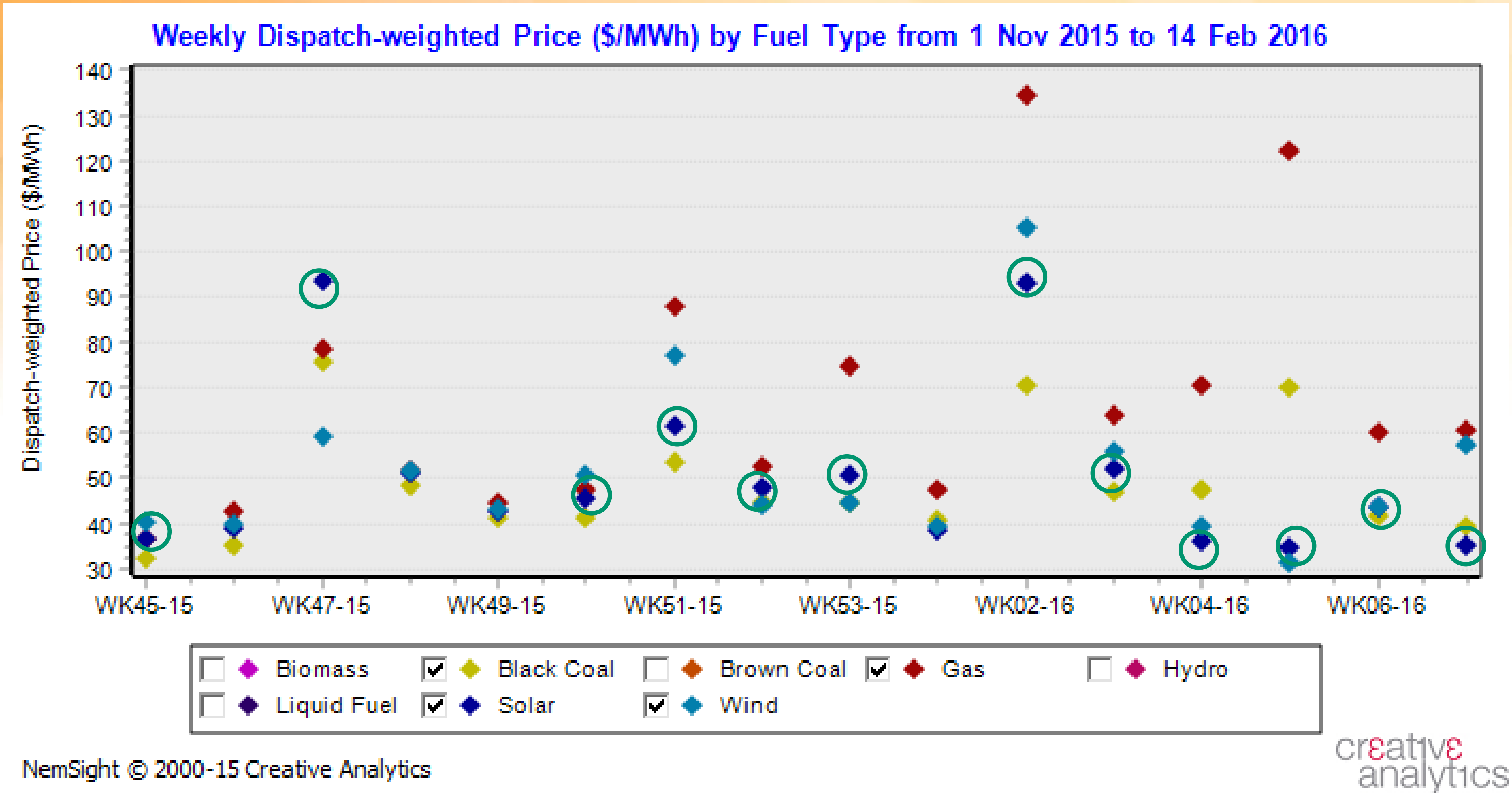
.. in a week of significant price variation



… hence variable spot market revenue



Weekly $/MWh varies considerably



Likely growing system balancing challenges with much higher PV penetrations

Variable & uncertain availability

Non-synchronous (no inherent inertia)

Increased variability in ‘net load’

Displacement of synchronous generation

FREQUENCY CONTROL

Matching demand and supply at all times

Minutes

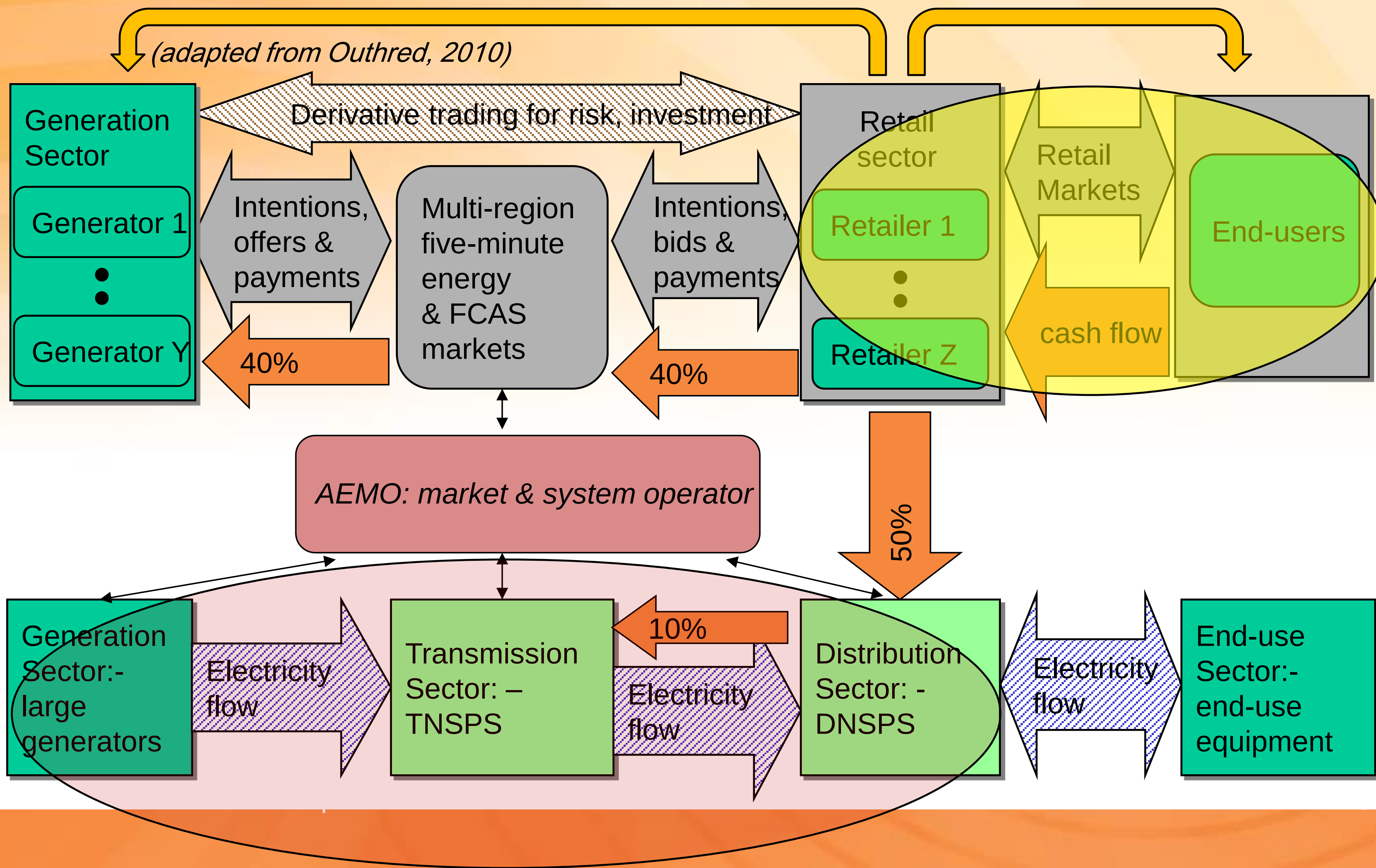
- *Regulation service* manages variability within 5min dispatch intervals
- Requirement will increase significantly
- Large value in optimisation ‘wrt both requirement and provision’

Seconds

- Operation of low inertia systems
- Many technical options – which are ‘technically feasible and most economically appropriate?
- Implementation mechanism required

(Riesz et al, 2015)

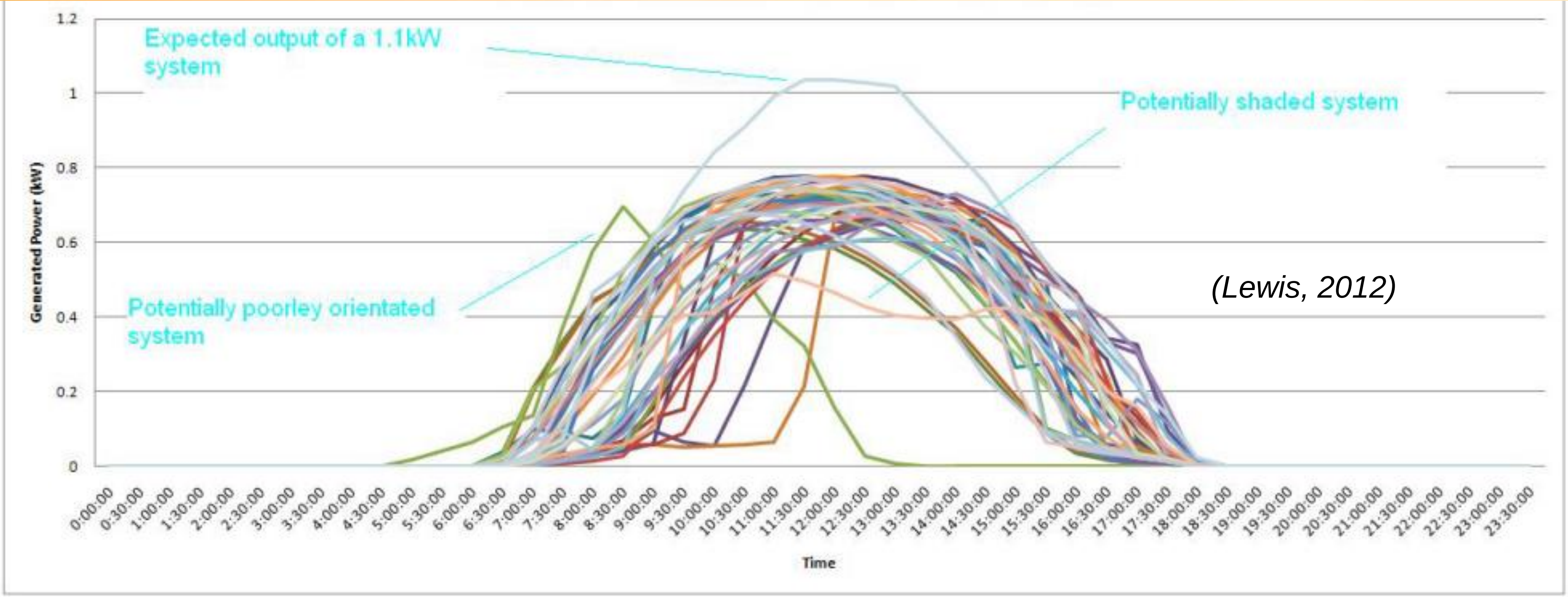
Australian NEM – regulatory, commercial regimes



Distributed PV value, market arrangements

- In many regards, economic value can be similar to utility PV
  - Generally not as well located in terms of solar resource
  - Operational performance is very mixed, typically lower than utility plant
  - Some potential additional benefits wrt location in terms of network losses, peak demand (can be costs too – eg. voltage management)
- In market terms
  - Reduces effective demand seen by wholesale market – already seeing ‘merit order’ impacts from reduced ‘sunny’ daytime demand
  - Resides within retail markets – typically net-metered with self-consumption reducing retailer sales, exports paid at around 25% of retail tariff. Tariffs themselves still generally flat c/kWh for smaller customers, TOU c/kWh and peak demand $/kVA charge for larger
  - Network tariffs generally highly economically inefficient with almost no locational pricing variation, flat for small customers, TOU and peak demand for larger. *Change to more Cost Reflective Tariffs underway*

Distributed PV – mixed and generally poorly monitored performance



(Lewis, 2012)

Figure 5-2: Generation profiles of 40 random 1.1kW systems in the Blacktown Area. Profiles are averaged over 4 sunny days in March. Also shown is the expected output of a 1.1kW system.

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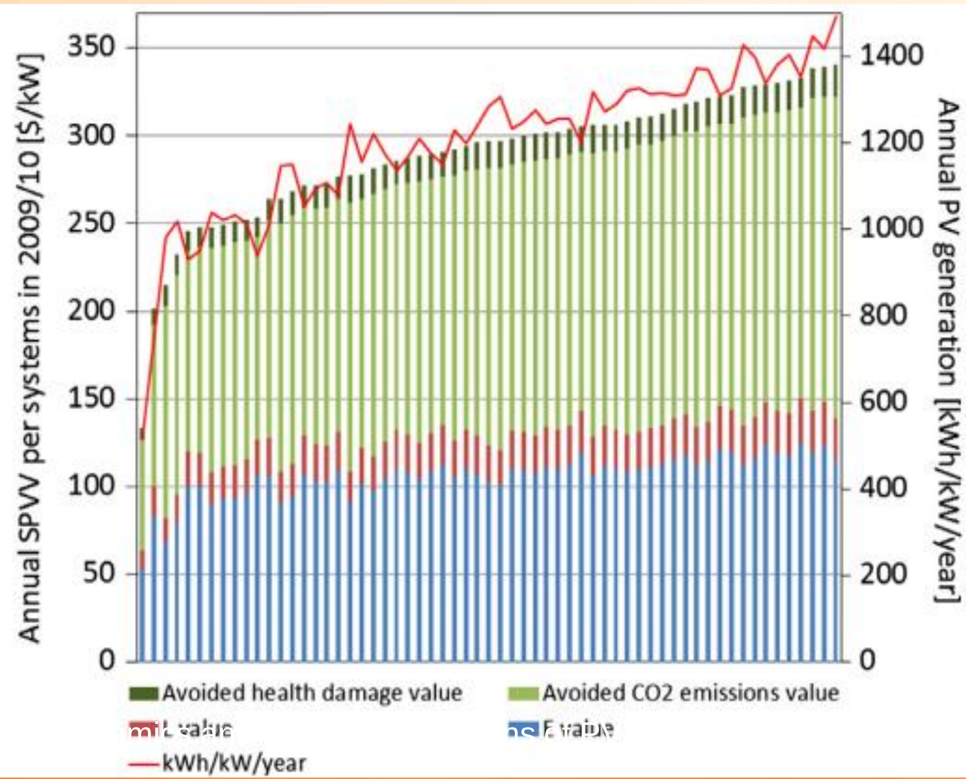
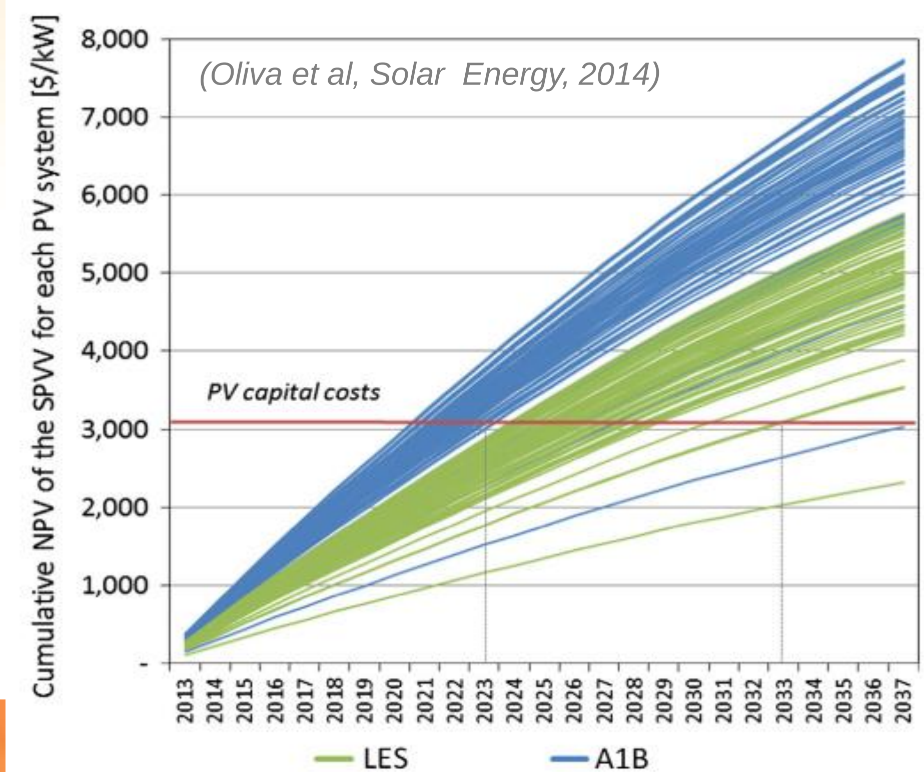
Household PV can offer socially beneficial NPV when including energy, losses, air pollution, climate change costs

Case Study: Australian NEM for (2009/10)			
PV output and NEM data		Input Parameters	
$PVelec_t$ [kWh]	Actual half-hourly PV generation data for 61 household PV systems.	*I [tCO_2/MWh]*	Intensity factor of CO_2 emission for each fossil fuel power plant in NSW.
w_t [$/MWh]	Actual half-hourly wholesale electricity prices for NSW.	*SCC [$/$tCO_2$]*	Social Cost of Carbon.
G_t [MW]	Actual half-hourly generation for each scheduled power plant in the NEM.	*H [$/MWh]*	Health damage costs of black coal, brown coal and natural gas power plants in Australia.
		LF [%]	Loss factor for the distribution area where the systems are located.

E value $/kWh → **L value** $/kWh → **ENV value** $/kWh →

Marginal Social PV Value [$/kWh]





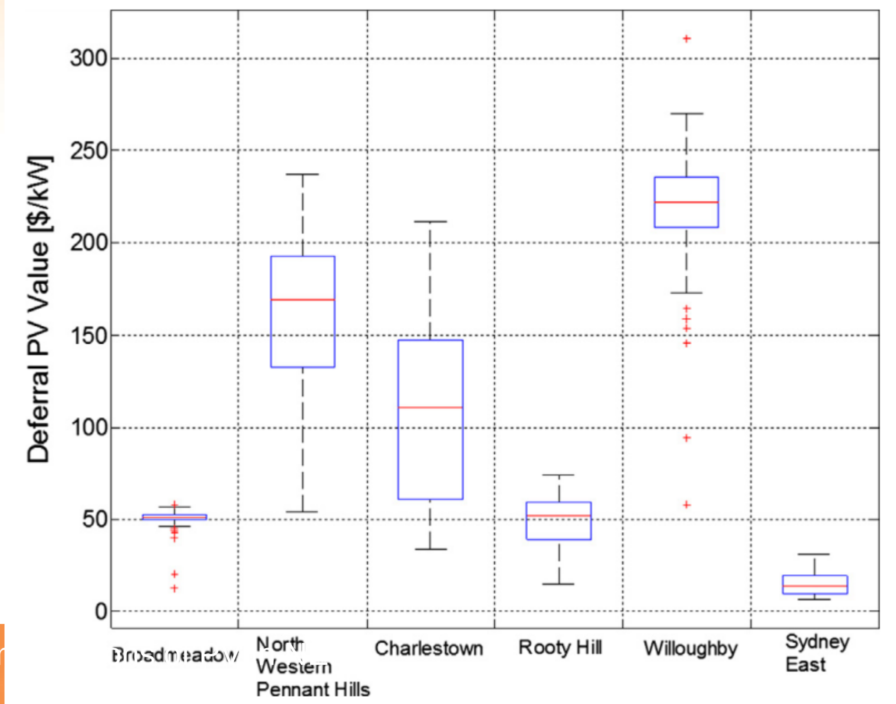
S. Oliva, I. MacGill, R. Passey (2014), “Estimating the net societal value of distributed household PV systems”, Solar Energy Journal, 100, p9-22.

Aggregated household PV may offer network value in some contexts too

Indicative values of deferral of network augmentation for six Area/Zone substations in Sydney.

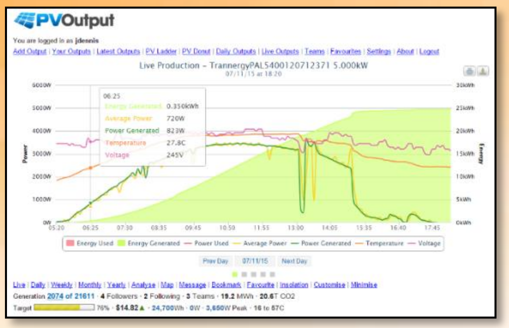
Area/Zone substation	Savings ($/kVA)	Reason
Broadmeadow	103	Cheaper new 2 × 37 MVA substation instead of new 2 × 50 MVA 132/11 kV that save $1.27 m[a]
Charlestown	799	Defer by 2 years new 132/11 kV Charlestown Substation whose cost is estimated at $40.5 m
North western pennant hills	608	Defer by 2 years new 11 kV cable whose cost is estimated at $3.75 m
Sydney east	161	Defer by 2 years new 33 kV feeder whose cost is estimated at $8 m
Willoughby	550	Defer by 1 year new 132/11 kV RNSH Substation whose cost is estimated at $30 m
Rooty hill	204	Defer by 2 year new North Glendenning Substation whose cost is estimated at $23 m

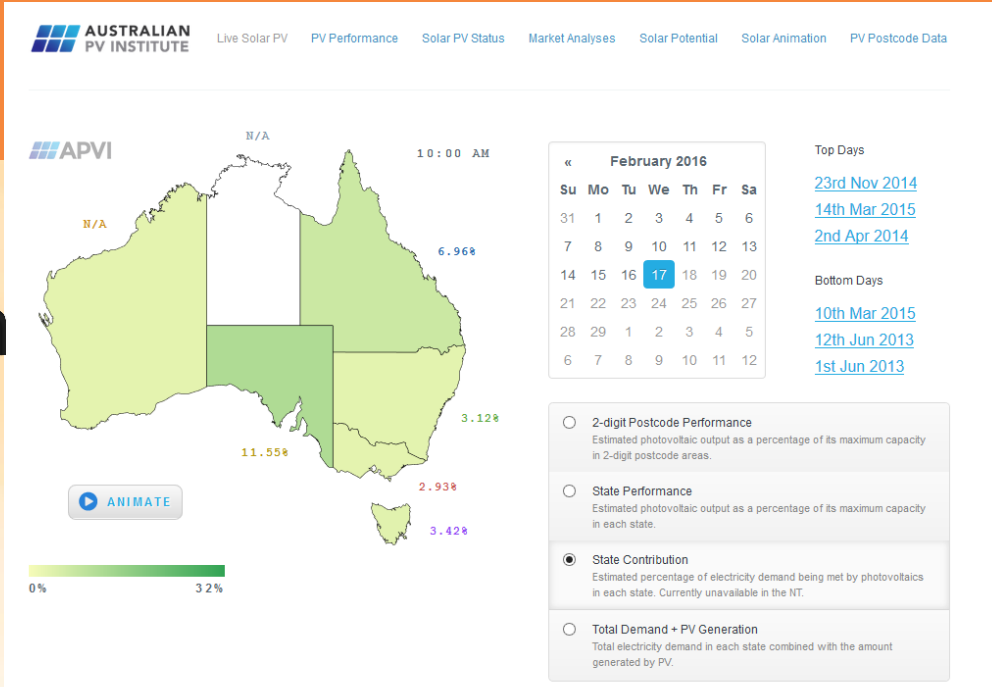
[a] ‘m’ Represents one million Australian dollars.

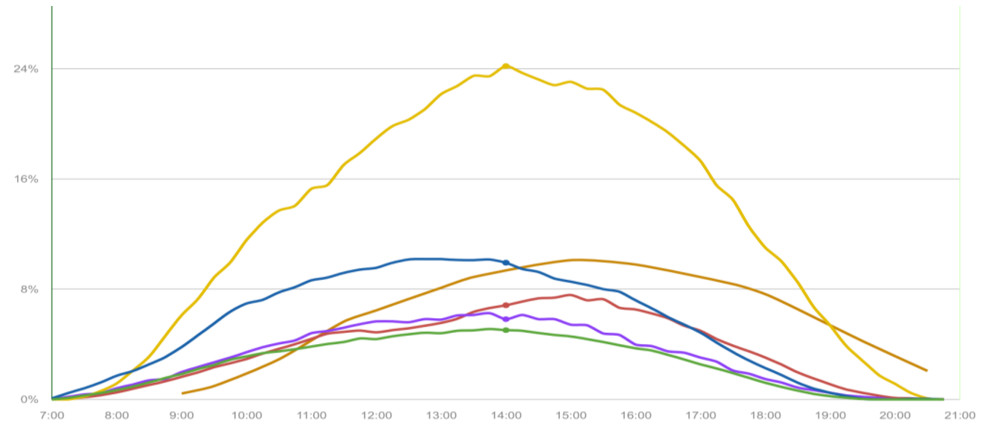


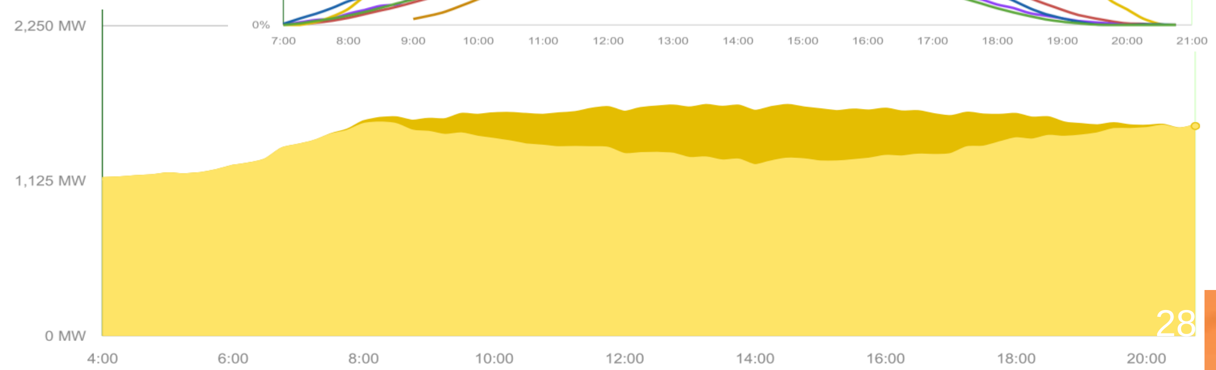
(Oliva et al, 2014)

Aggregated operation, hence value proposition



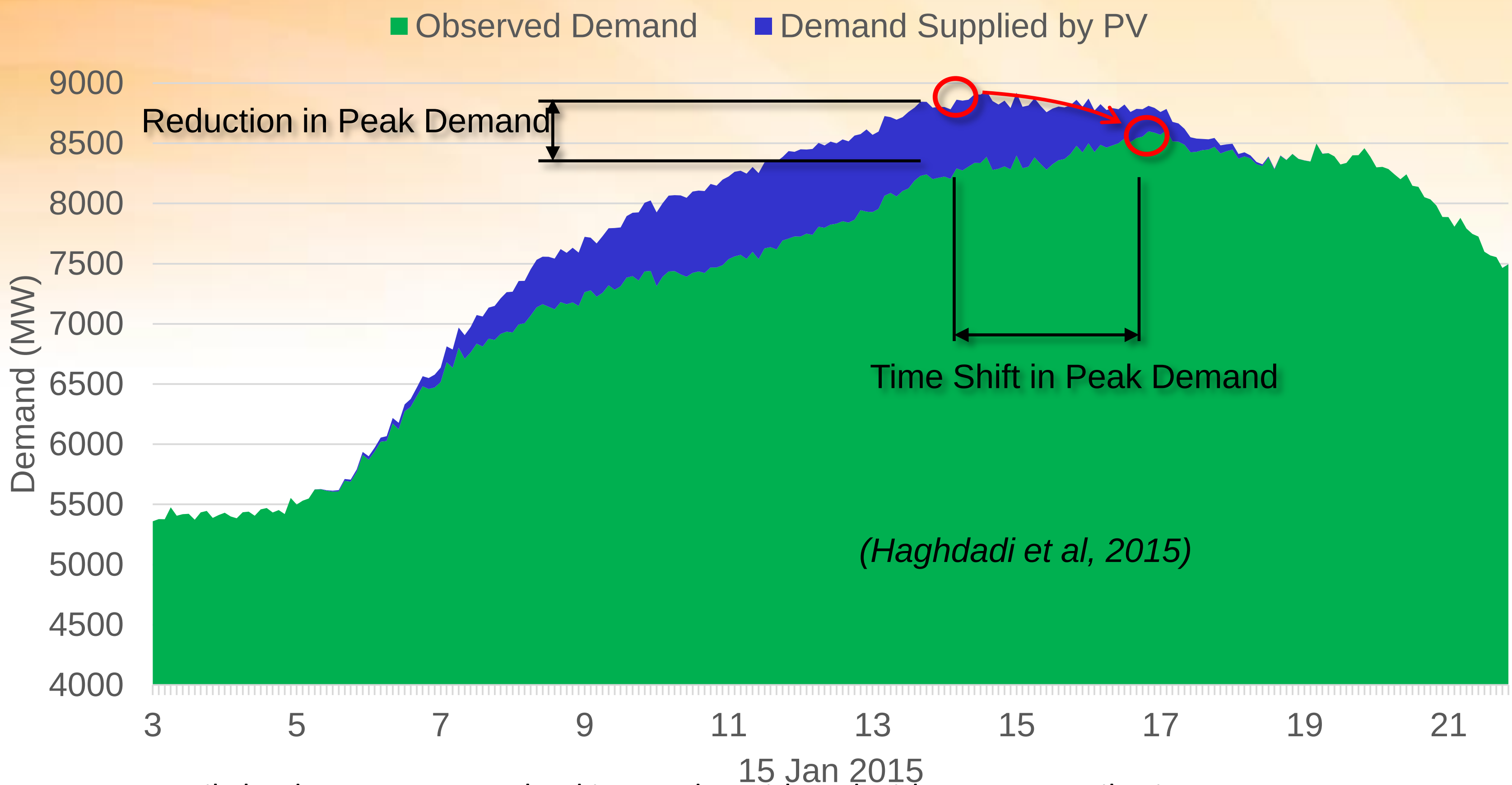






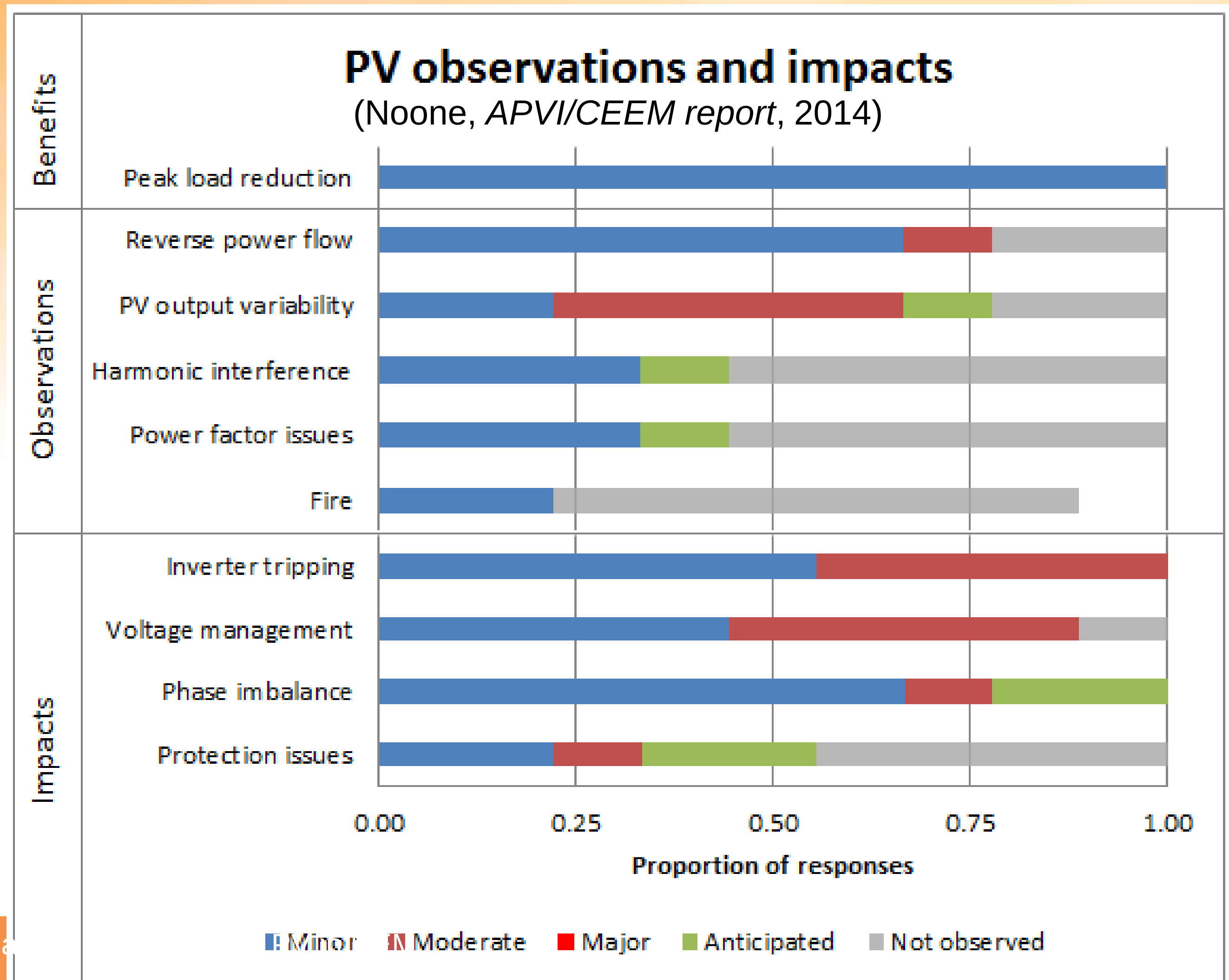
Potential peak demand reductions

hence generation and network investment reductions although these will generally decline as penetrations grow



Daily load pattern Queensland in one day with and without PV contribution.

Possible adverse impacts, hence additional costs for Distribution Network Service Providers as well

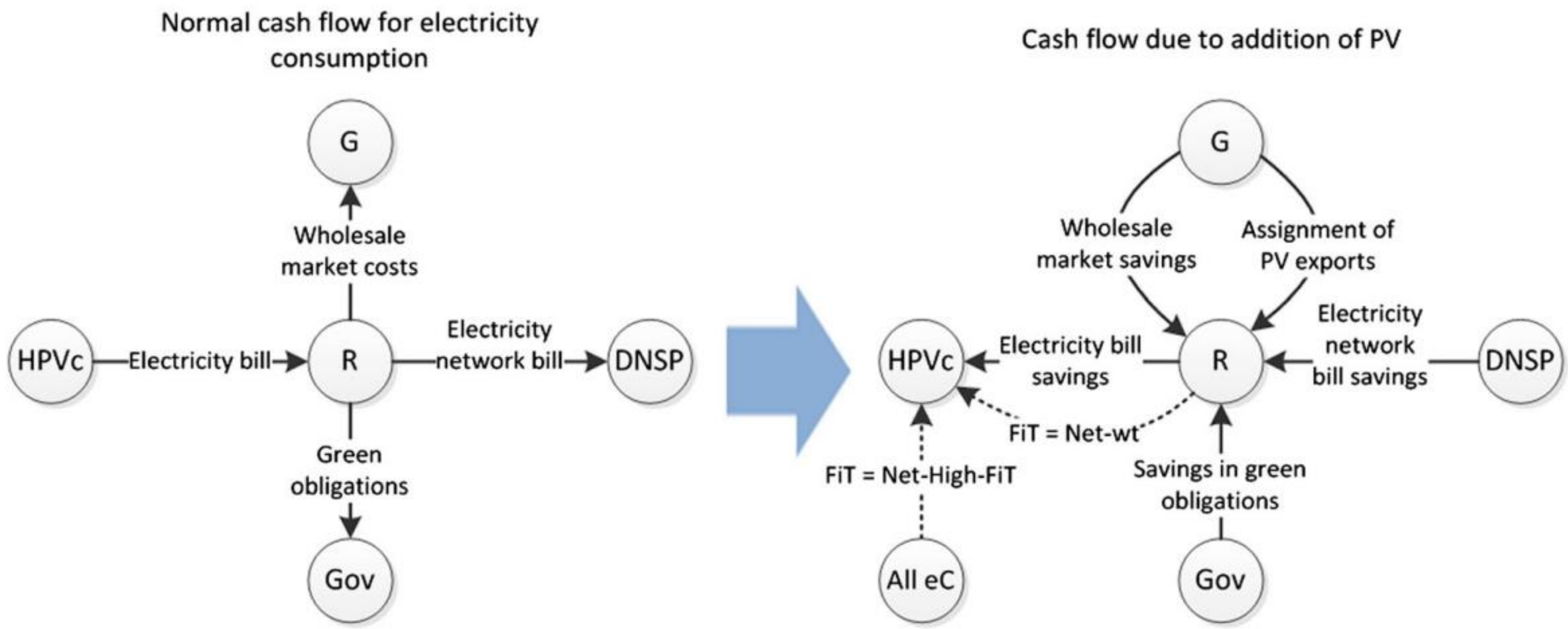


Possible economic implications

- PV doesn’t ‘cause’ most of these adverse impacts – an outcome of characteristics of all resources connected to network including demand as well as PV
- Managing impacts not a question of technical feasibility but of economics, broader considerations
  - What are our most economically appropriate responses?
    Some low cost options that can do most of what much higher cost options (such as storage) might do
  - Who should pay?
    Within broader constraints set by electricity industry’s key role providing an essential public good

The real challenge at present – mismatch b/n economics and present commercial incentives

PV changes the money flows ….



(Oliva et al, 2015)

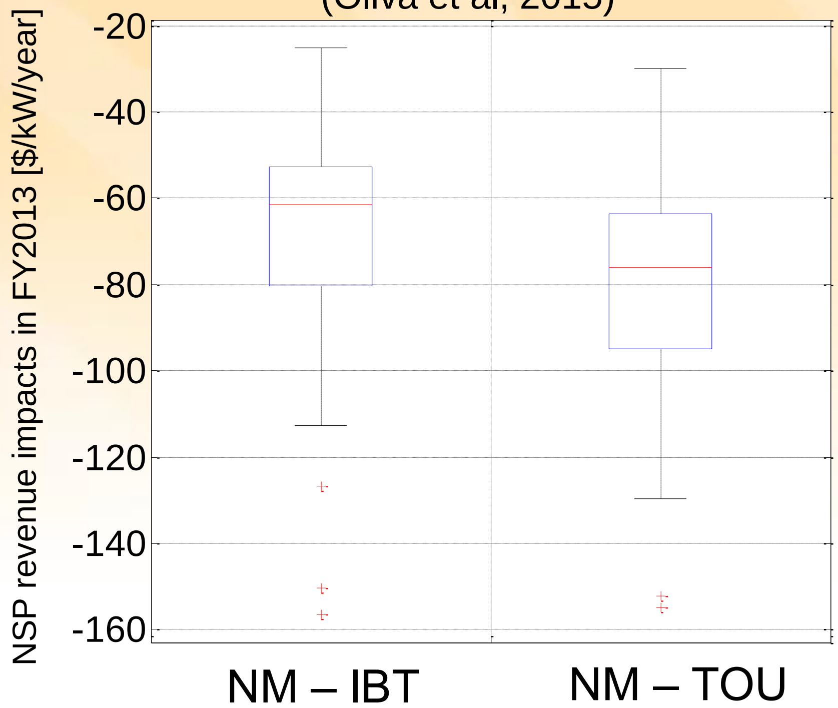
HPVc: Household PV customers
R: Electricity retailers
DNSP: Distribution network service providers

G: Generators
Gov: NSW government
All eC: All electricity customers

Potentially highly adverse revenue impacts on retailers, DNSPs

- Net metering with low export rate favors household self consumption with volume based flat, TOU tariffs
- Possible major revenue impacts for key industry stakeholders

(Oliva et al, 2015)



(Ausgrid/IPART, 2012)

PV unit size	Median annual net exports (kWh)	Median daily net exports (kWh)	Median annual export ratio
1.0 kW	393	1.1	32%
1.5 kW	616	1.7	35%
2.0 kW	1,007	2.8	41%
3.0 kW	1,703	4.7	49%
4.0 kW	2,378	6.5	52%
5.0 kW	2,921	8.0	50%

Possible industry responses

- For DNSPs, monopoly economic regulation with revenue cap based on approved expenditure can correct revenue shortfalls over time… *death spiral?*
- Resetting tariffs – greater fixed charges, Solar specific tariffs and charges to address cross-subsidies between PV and non-PV households…

However, potentially discriminates against PV while allowing far greater cross subsidies b/n customers due to other causes such as air-conditioning, urban vs rural locations, to remain.
Is this an appropriate incentive structure for an industry in desperate need of clean energy transition?

Looking forward

Comprehensive and coherent policy development process required across all domains

1. Regulation	2. Market Design	3. External Policy Drivers
• Transmission network planning • Distribution network planning • Grid codes	• Fundamental market design • Spot market rules • Ancillary service market rules • Retail markets	• Carbon policies • Renewable & energy efficiency policies • Fuel policies • Broader relevant policies

Robustness and Resilience: ability to perform reasonably well under a wide range of possible futures

(from Riesz et al, 2015)

Some key needs and hence opportunities

- new regulatory frameworks and business models for DNSPs, other key stakeholders that facilitate their active support forintegration of appropriate distributed energy options including PV in a manner that will help us meet the economic, social and environmental challenge of a clean energy future
- further progress on current wholesale market arrangements, and greater RE participation in these
- Policies to effectively price what are currently environmental externalities associated with conventional generation
- *Proactive efforts to understand and improve the value PV brings to the electricity industry before penetrations grow too great will be particularly valuable*

Thank you, questions and discussion

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