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

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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

(source IEA, PVPS snapshot of global PV markets)

(Brundinger, Task 14 Update, 2015)
Australian PV penetration significant

**FIGURE 22:** PV CONTRIBUTION TO THE ELECTRICITY DEMAND IN 2014

(IEA PVPS, Trends 2015)
and largely a household story to date

...although commercial and utility scale PV now growing fast

(EAPVI, PV in Australia, 2015)
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)

11:50 am
- NSW: 3.73%
- QLD: 9.48%
- SA: 23.26%
- VIC: 7.5%
- WA: 9.83%

(APVI, Solar map website, 2014)
The Australian National Electricity Market

Economics and market implications of PV in NEM

Source: 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)

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

(Economics and market implications of PV in NEM (APVI, PV in Australia, 2015))

Table 16: Estimated PV-related labour places in 2014

<table>
<thead>
<tr>
<th>Category/Size</th>
<th>Typical applications and brief details</th>
<th>Current prices per W</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFF-GRID Up to 1 kW</td>
<td>Water pumps, lighting, remote homes</td>
<td>AUD 9 - AUD 15</td>
</tr>
<tr>
<td>OFF-GRID &gt;1 kW</td>
<td>Pastoral systems</td>
<td>AUD 7,50/W – AUD 11/W</td>
</tr>
<tr>
<td></td>
<td>Telecommunications / mining power systems</td>
<td>AUD 22/W – AUD 60+/W</td>
</tr>
<tr>
<td>Grid-connected Rooftop up to 10 kW (residential)</td>
<td>Residential</td>
<td>AUD 1,95</td>
</tr>
<tr>
<td>Grid-connected Rooftop from 10 to 250 kW (commercial)</td>
<td>Commercial rooftop</td>
<td>AUD 1,78</td>
</tr>
<tr>
<td>Grid-connected Rooftop above 250 kW (industrial)</td>
<td>Larger rooftops</td>
<td>AUD 1,80</td>
</tr>
<tr>
<td>Grid-connected Ground-mounted above 1 MW</td>
<td>Solar farms</td>
<td>AUD 1,80</td>
</tr>
<tr>
<td>Research and development (not including companies)</td>
<td></td>
<td>400</td>
</tr>
<tr>
<td>Manufacturing of products throughout the PV value chain from feedstock to systems, including company R&amp;D</td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>Distributors of PV products</td>
<td></td>
<td>200</td>
</tr>
<tr>
<td>System and installation companies</td>
<td></td>
<td>10,500</td>
</tr>
<tr>
<td>Electricity utility businesses and government</td>
<td></td>
<td>500</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td>3,000</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>14,620</td>
</tr>
</tbody>
</table>
AEMO: market & system operator

(A adapted from Outhred, 2010)
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

- COMPETITIVE PPA, 1.1%
- FEED-IN TARIFF THROUGH TENDER, 5.6%
- INCENTIVIZED SELF-CONSUMPTION OR NET-METERING, 16.0%
- NON-INCENTIVIZED SELF-CONSUMPTION, 0.2%
- DIRECT SUBSIDIES OR TAX BREAKS, 16.1%
- TRADING OF GREEN CERTIFICATES OR SIMILAR RPS-BASED SCHEMES, 2.4%
- FEED-IN TARIFF (FOR THE ENTIRE PRODUCTION), 58.6%

(IEA PVPS, Trends 2015)
Australian NEM – regulatory, commercial regimes

(adapted from Outhred, 2010)

- **Generation Sector**
  - Large generators
  - Intentions, offers & payments
  - 40%

- **Transmission Sector**
  - TNSPS
  - Electricity flow
  - 10%

- **Distribution Sector**
  - DNSPS
  - Electricity flow
  - End-use equipment
  - 50%

- **Retail Sector**
  - Retailers 1 & Z
  - Intentions, bids & payments
  - Multi-region five-minute energy & FCAS markets
  - 40%

- **AEMO: market & system operator**

- **End-users**
  - Cash flow

(Generation, transmission, distribution, retail, and end-use sectors are interconnected through various market mechanisms, including derivative trading for risk and investment.)

(adapted from Outhred, 2010)
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

(Eriesz et al, 2015)
Australian NEM – regulatory, commercial regimes

(adapted from Outhred, 2010)

Generation Sector

Generator 1

Generator Y

Derivative trading for risk, investment

Intentions, offers & payments

Multi-region five-minute energy & FCAS markets

Intentions, bids & payments

Retail sector

Retailer 1

Retailer Z

End-users

Retail Markets

cash flow

AEMO: market & system operator

40%

40%

40%

50%

End-use Sector: - end-use equipment

Generation Sector: - large generators

Electricity flow

Transmission Sector: - TNSPS

Electricity flow

Distribution Sector: - DNSPS

Electricity flow

Retail Markets

cash flow

Retailer 1

Retailer 2

Retailer Z

End-users
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

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.

(Lewis, 2012)
Household PV can offer socially beneficial NPV when including energy, losses, air pollution, climate change costs.
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.

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

* ‘m’ Represents one million Australian dollars.

(Oliva et al, 2014)
Aggregated operation, hence value proposition

Economics and market implications of PV in NEM
Potential peak demand reductions hence generation and network investment reductions although these will generally decline as penetrations grow

Reduction in Peak Demand

Time Shift in Peak Demand

(Haghdadi et al, 2015)

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.

PV observations and impacts

(Noone, APVI/CEEM report, 2014)
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)
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

(Ausgrid/IPART, 2012)

<table>
<thead>
<tr>
<th>PV unit size</th>
<th>Median annual net exports (kWh)</th>
<th>Median daily net exports (kWh)</th>
<th>Median annual export ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 kW</td>
<td>393</td>
<td>1.1</td>
<td>32%</td>
</tr>
<tr>
<td>1.5 kW</td>
<td>616</td>
<td>1.7</td>
<td>35%</td>
</tr>
<tr>
<td>2.0 kW</td>
<td>1,007</td>
<td>2.8</td>
<td>41%</td>
</tr>
<tr>
<td>3.0 kW</td>
<td>1,703</td>
<td>4.7</td>
<td>49%</td>
</tr>
<tr>
<td>4.0 kW</td>
<td>2,378</td>
<td>6.5</td>
<td>52%</td>
</tr>
<tr>
<td>5.0 kW</td>
<td>2,921</td>
<td>8.0</td>
<td>50%</td>
</tr>
</tbody>
</table>
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
- Transmission network planning
- Distribution network planning
- Grid codes

2. Market Design
- Fundamental market design
- Spot market rules
- Ancillary service market rules
- Retail markets

3. External Policy Drivers
- 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 for integration 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