

End-of-life management of Si PV modules: The forgotten case of “reuse”

Dr Rabin Basnet
rabin.basnet@anu.edu.au

School of Engineering, The Australian National University

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Australian
National
University

Outline

- ❖ End-of-life Management of Si PV?
- ❖ What is PV reuse?
- ❖ Current status of modules reuse?

Why don't old solar panels ever retire?
Because they're too busy shining in their second careers!



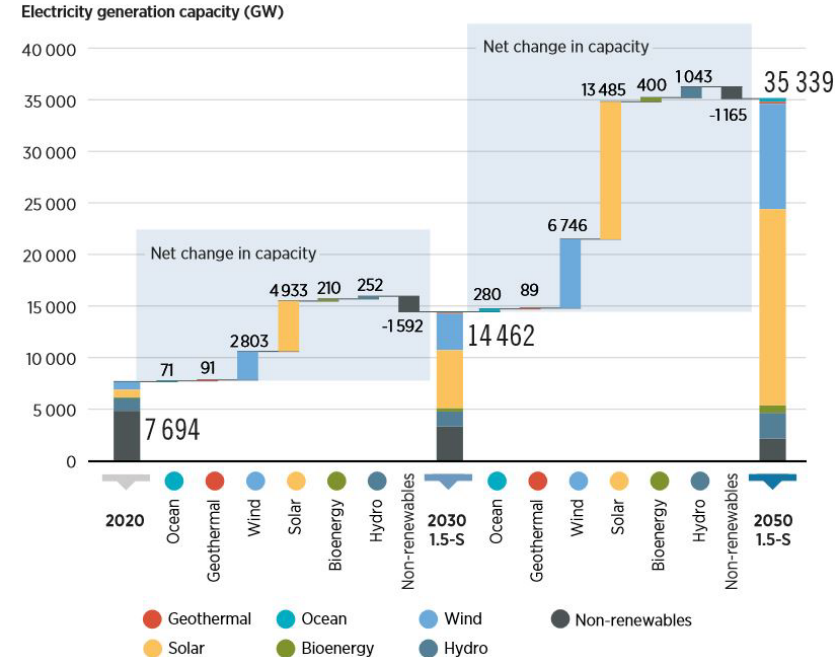
Silicon photovoltaics

- ❖ Minimum goal: global temperature rise $< 1.5^{\circ}\text{C}$.
- ❖ Requires a massive expansion of renewable energy source production and installation.
- ❖ PV deployment is increasing exponentially.
- ❖ We need aggressive TW-level of deployment annually.

TABLE 1: TOP 10 COUNTRIES FOR ANNUAL AND CUMULATIVE INSTALLED CAPACITY IN 2023

FOR ANNUAL INSTALLED CAPACITY				FOR CUMULATIVE CAPACITY			
1		China	235.5 GW*	1		China	662.0 GW*
(2)		European Union	55.8 GW	(2)		European Union	268.1 GW
2		United States	33.2 GW	2		United States	169.5 GW
3		India	16.6 GW	3		India	95.3 GW
4		Germany	14.3 GW	4		Japan	91.4 GW
5		Brazil	11.9 GW	5		Germany	81.6 GW
6		Spain	7.7 GW	6		Spain	37.6 GW
7		Japan	6.3 GW	7		Brazil	35.5 GW
8		Poland	6.0 GW	8		Australia	34.6 GW
9		Italy	5.3 GW	9		Italy	30.3 GW
10		Netherlands	4.2 GW	10		Korea	27.8 GW

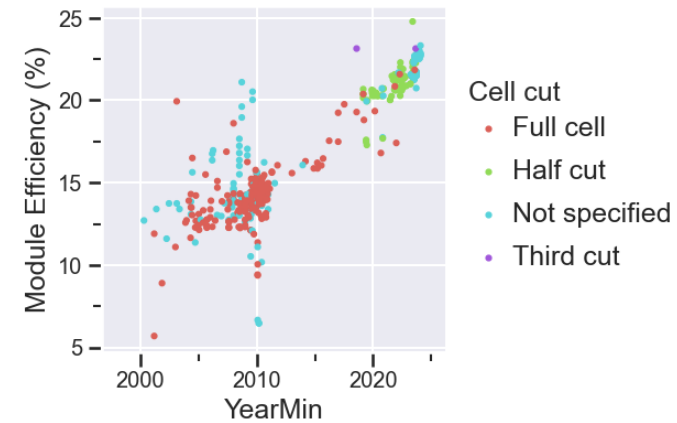
Total global electricity generation capacity expansion needed by 2030 and 2050 to realise the 1.5°C Scenario



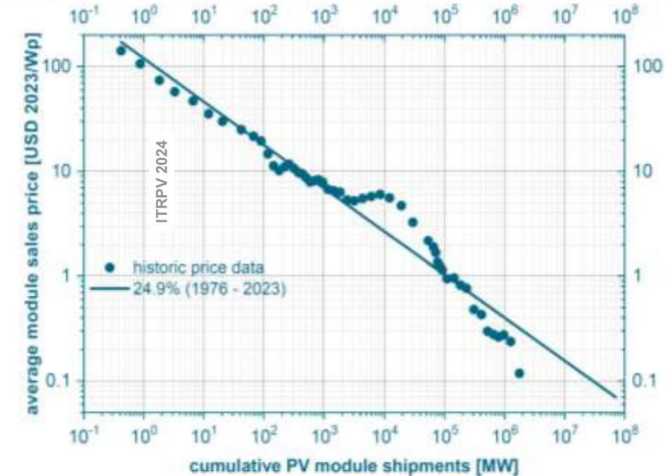
Learning curve

- ❖ PV has unprecedented learning rate of approx. 25% (2023).
 - ✓ Improved module efficiency.
 - ✓ Continue cost optimization along the entire value chain.
 - ✓ Market differentiation.
- ❖ We expect further reduction of cost by innovation along the supply chain.
- ❖ Increased electrification (*absolute necessity*)

❖ Could we see a rise in “fast PV”, like the solar world’s answer to “fast fashion”? (cautiously)



Learning curve for module price as a function of cumulative shipments



Technical life

CO₂ payback time is 2-3 years.

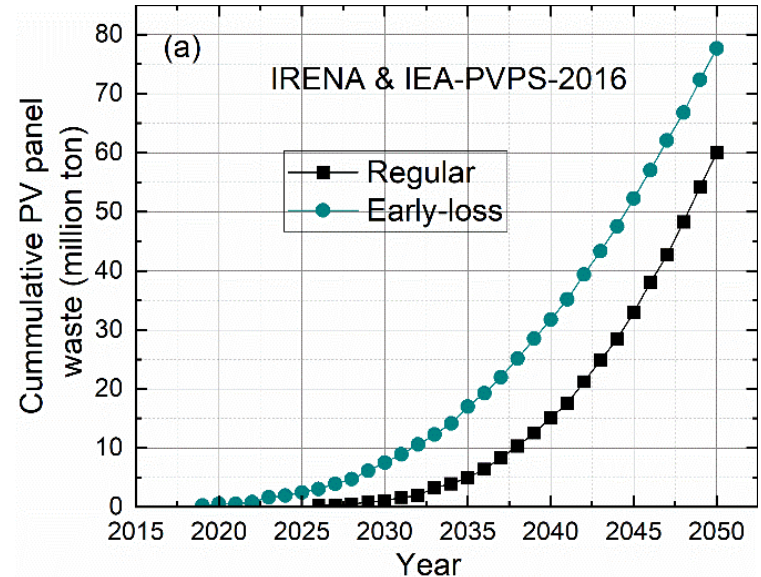
- ❖ Technical/service life of Si PV modules 25-30 years.
- ❖ In reality significant volume of modules are decommissioned < 15 years.
 - ❖ Repowering
 - ❖ Damage and technical failures
 - ❖ Continuous degradation.
 - ❖ Economic motivation

Neoen shut down Australian solar-plus-storage plant after 7 years

The DeGrussa solar and battery hub in remote Western Australia – the largest integrated off-grid solar and battery storage facility in Australia when it was deployed – has reached end of life, says asset owner Neoen.

JANUARY 18, 2024 DAVID CARROLL

MARKETS UTILITY SCALE PV UTILITY SCALE STORAGE AUSTRALIA



Research gap: Define remaining useful life.



Current practice: Linear economy



- Decommissioned modules are either stockpiled or landfilled.
- EU's WEEE directive has established a separate category for PV modules.
- Under WEEE, the PV producer are mandated to retrieve and recycle decommissioned modules and achieve an **80% (by wt)** recycling rate.
- **Landfill disposal will be banned.**
- In Australia, some states (Vic & SA) have banned landfilling of PV modules.

Negative headlines

The dark side of 'green energy' and its threat to the nation's environment

What happens to old solar panels, windmills an

Published: Jan 30, 2021, 10:00 p.m

Rising power costs worsening solar panel e-waste crisis as people replace panels prematurely

ABC Gippsland / By Natasha Schapova

Posted Thu 8 Jun 2023 at 6:04am, updated Thu 8 Jun 2023 at 7:16am

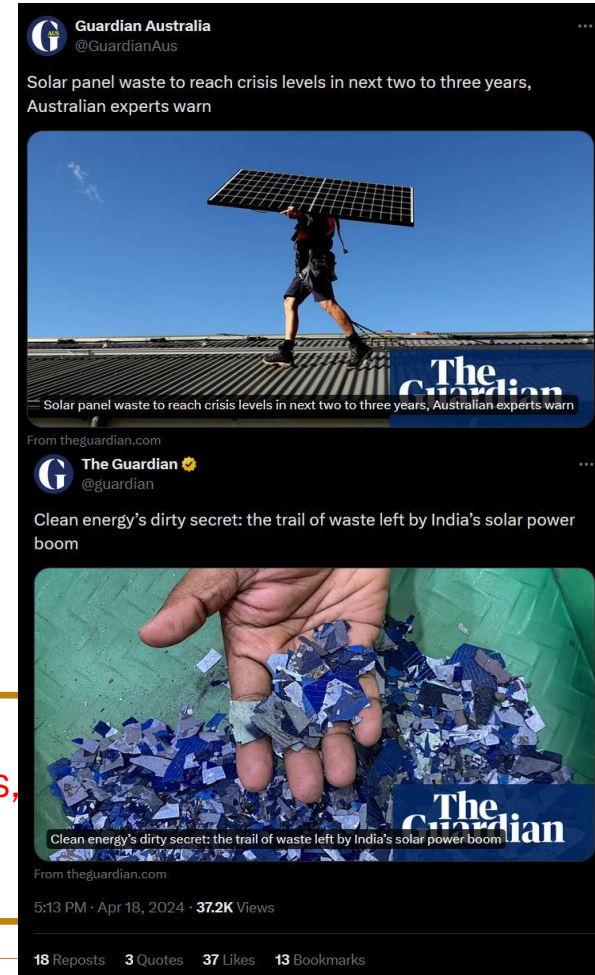
The Renewable Energy Boom is a Waste Problem

By Felicity Bradstock - Apr 25, 2024, 9:11 AM CDT

English

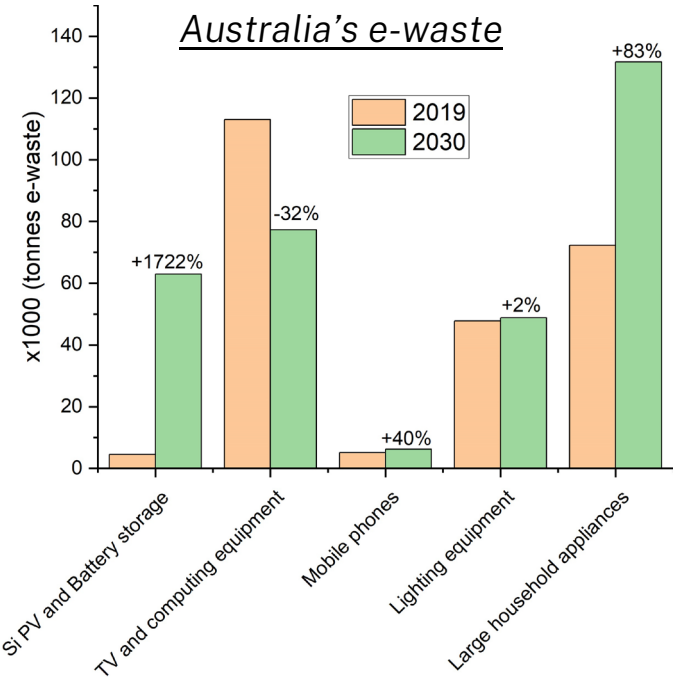
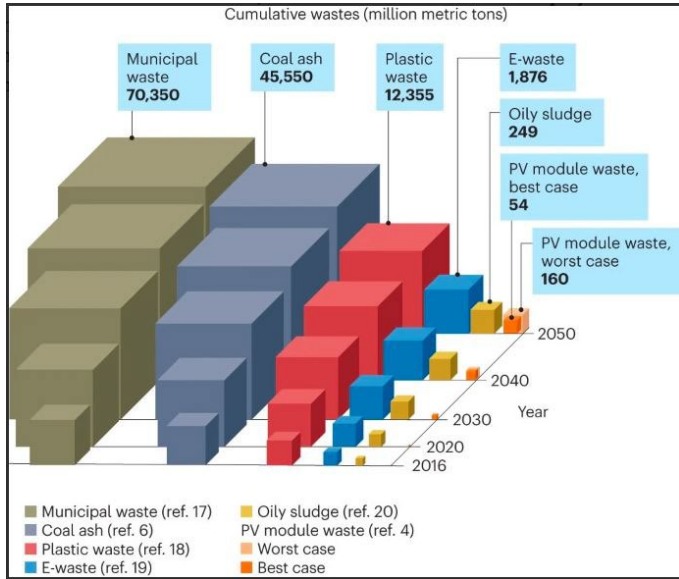
- ▶ Renewable energy waste is a growing problem due to the increasing use of solar panels and wind turbines.
- ▶ Improper disposal of renewable energy equipment can lead to environmental and health problems.
- ▶ Governments need to establish clear standards and regulations for energy waste disposal to ensure that it is done safely and responsibly.

Negative headlines sensationalise or distort facts, leading to public misinformation!!!!



Bigger picture of waste

- ❖ PV waste is small compared to total waste volume.
- ❖ Less than 10% of e-waste.
- ❖ *Do we need to worry?*



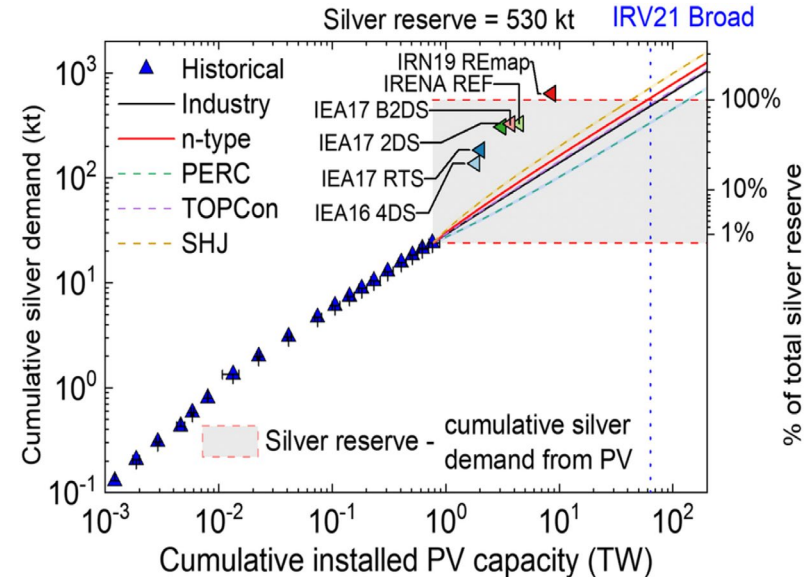
- EoL PV +1722%, 2030 compared to 2019 in Australia, assuming 22.5-year average lifetime.
- The fastest growing waste stream in Australia.



Resources dilemma!!

- ❖ PV is using 12.7% of global Ag supply annually in 2020.
- ❖ With the exponential rise of PV deployment, **Ag** and **Cu** consumption is expected to rise.
- ❖ Other critical minerals, such **Indium, Bismuth**
- ❖ Vast demand of glass, silicon might overwhelm alternative markets.

- ❖ Is it exaggeration?
 - ❖ Renewable energy transition should be sustainable in itself!!!



The silver learning curve for photovoltaics and projected silver demand or net-zero emissions by 2050

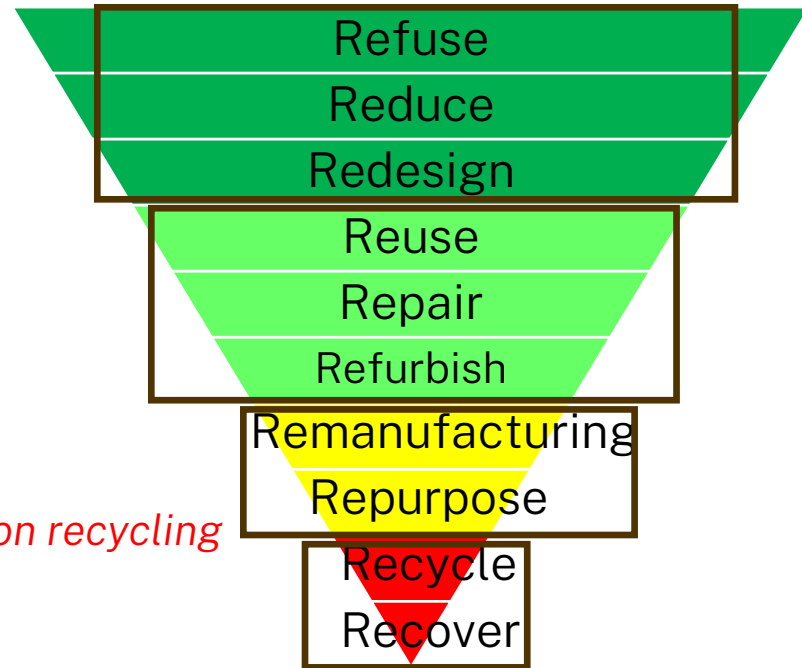


What is the alternative?

Circular economy

- 10 R strategies
 - Design
 - Consumption
 - Return
- Extension of useful life should be practiced before recycling.
 - Embedded energy
 - Might not be universal.

❖ *The current focus in the EoL is often more on recycling rather than reuse.*



What is PV reuse

- Reuse: Reinstallation of decommissioned PV modules in other locations after appropriate quality control.
- Reuse of modules \neq reuse of parts
- Commonly referred as “Pre-loved” “Second hand” “Repaired”.
- Reuse journey starts from decision to decommission
- Reuse via repair and refurbish adds extra steps.
- Reuse opens new business opportunities.

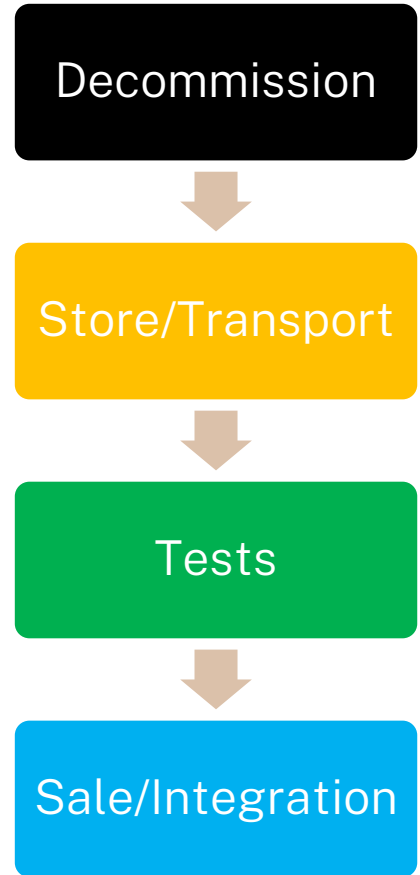
❖ *“Reuse” should include whole balance of system.*

➤ Recyclers

- Recycler might consider it as a delayed customer.

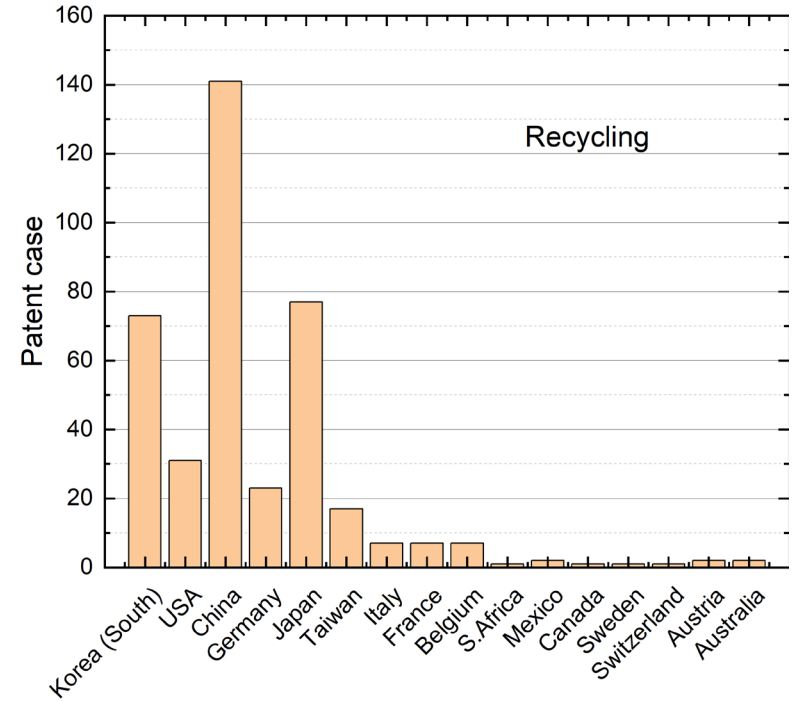
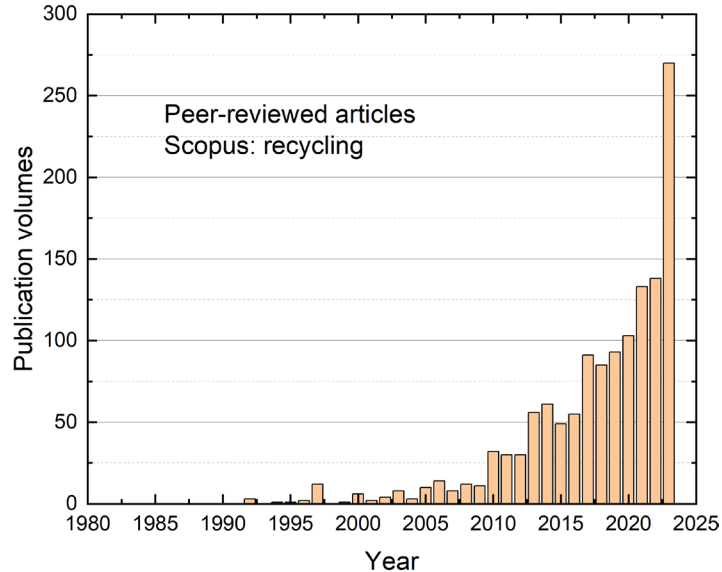
➤ PV manufacturers

- Competitor of market share!!!



Data on EoL of PV modules

- ❖ Peer-review articles publication volumes
- ❖ Patent applications
- ❖ Industry reports
- ❖ PV recyclers



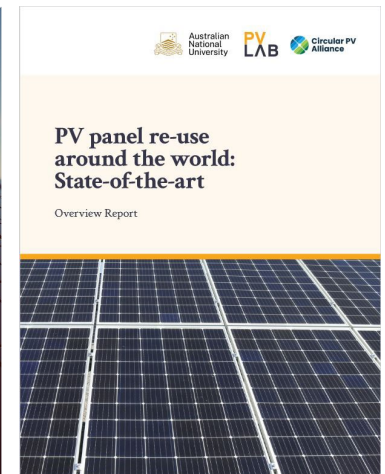
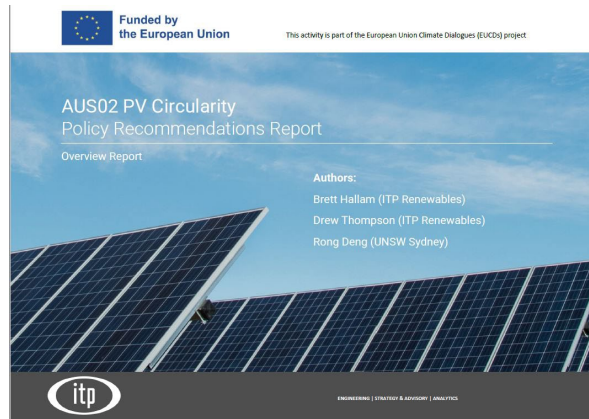
- 50+ articles from Australian researchers on recycling
- <20 of peer reviewed articles on the “re-use” of PV modules in total.



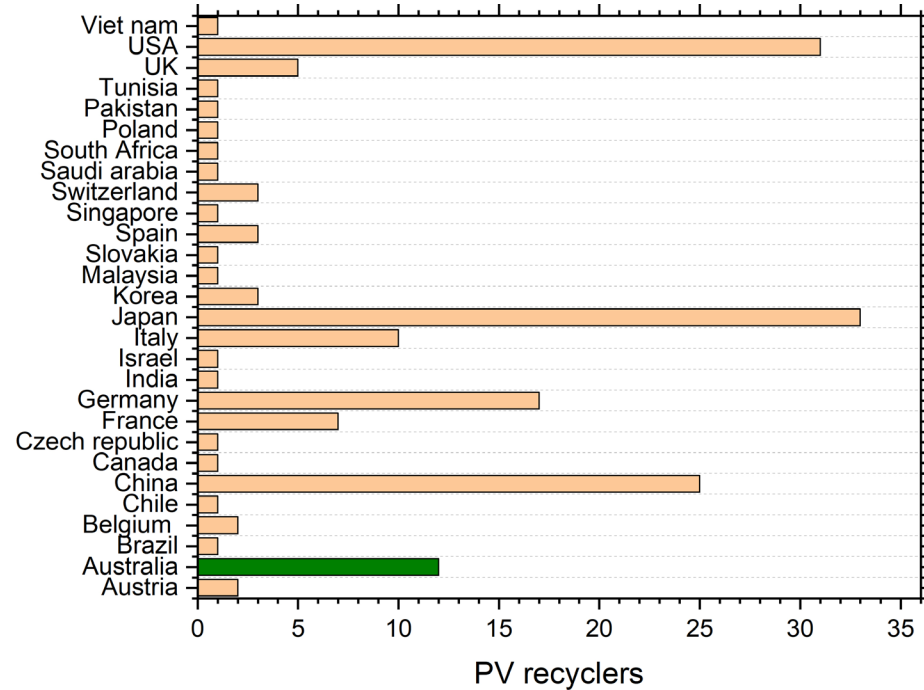
PV-reuse reports (Australia)

- Australia has recognized the potential of re-use.
- Several industry reports are published realizing the potential of PV reuse.
- Lacks more scientific analysis.

Smart Energy Council's report



PV recyclers

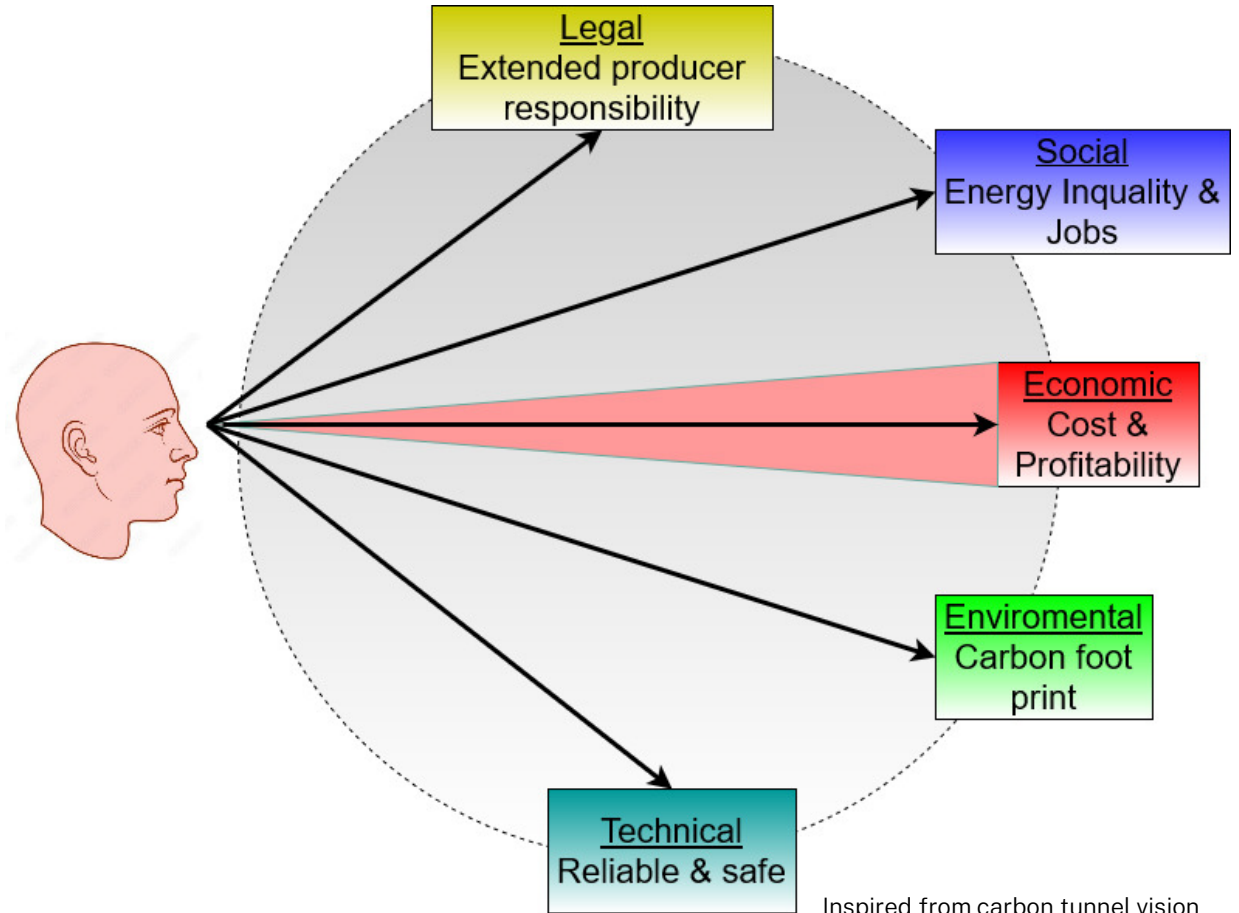


Australian PV recyclers	
PV reclaim	WA, Q
Blue Tribe	NSW
Cyber recycling & disposal Pty. Ltd	WA
Elecsome Pty. LTD, Ojas Group	Vic
Infoactive Group	Vic
Lotus Energy Recycling	Vic
PV Industries Pty. Ltd	NSW
Solar Professional (KGM services)	NSW
Solar recovery Corp.	Vic
Total Green recycle	WA
PV lab Australia	ACT

- Down-cycling junction box and Al frames and concrete mix.
- Two businesses are working on “reuse” of PV modules.



Perspectives for successful PV reuse



Inspired from carbon tunnel vision



Legal perspectives



- ❖ Lacks regulatory frameworks for reused PV.
- ❖ In Australia, AS/NZS 5033 solar standard restrict the reuse of PV in grid connected systems.
- ❖ The *Small-scale Technology Certificate* scheme hasn't recognized "reuse" modules. After 2030, there can be a room for it.
- ❖ **Solar stewardship**
 - ❖ Reuse, reclaim and recycle (of whole system)

Research gaps: Develop regulatory framework.
: Incentive mechanisms.

Drivers

Barriers

Sustainable product lifecycles

Repair warranties

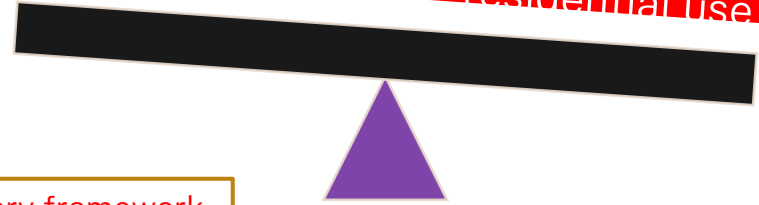
Landfill bans

Lack of manufacturer's responsibility

Project developer's liability

Insurance compliance

Warranty limitations, and compliance for residential use



Technology: literature review

Ref	Sample size	Panel age (years)	Tests	Country	Criteria	Reusability (%)
Shah	25	6-12	VI, IV, TI	Australia		NA
Stromberg	221	2-20	VI,IV,TI	USA		64
Stochek	204	19-23	VI,IV,TI	Italy	Pmpp>80%	65
Rabanal	1000	NA	VI,IV,TI	Chile	Pmpp>40%	30-34
Nieto-Morone	NA	NA	VI,IV,TI EL,	Spain	Pmpp>80%	87
PV lab	96	NA	VI, IV, EL	Australia		96%

- Si PV technology is changing cell, module technology, size, power..
- Unavailability of spare parts.
- Lack of standardized processes and criteria.

Research gap: Criteria for reusability?

VI: visual inspection
TI: thermal imaging
EL: electroluminescence
IV: current-voltage



Example of PV reuse



“Black boxes” at collection points

- Quickly test
- Cheaply test
- Sort panels: A, B, no-grade

Black boxes

- Don't exist ... yet
- Tests
 - ✓ “Safety should be prioritized”



Mobile Test rig “white box”

- Focus on electrical performance.
- Tests and provide warranties.
- Machine learning?

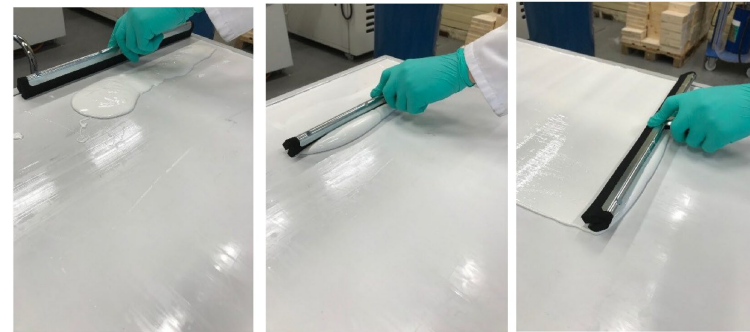
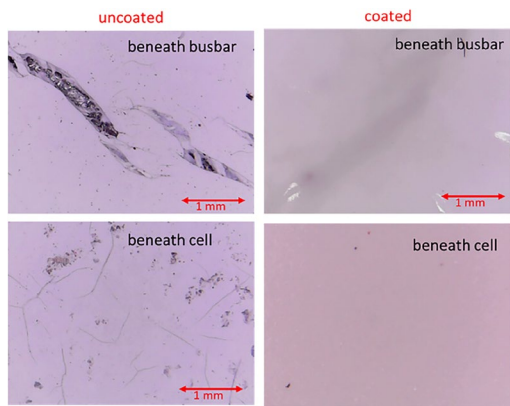


Research gaps: Product development
Data of decommissioned PV modules



Experimental work

- ACT government funded R2 project: Reduce and Reuse-keeping PV panels out of waste stream.
- Repair cracked Backsheet using flowable silicone sealant.
- The method fills the cracks present in the backsheet with an insulating material, restoring insulation resistance.
- Test the reliability of the coating using IEC6125 standard.



Technology: Drivers



Improving solar performance through drone testing

A collaboration between PV Lab Australia and QE-Labs Singapore is bringing electroluminescence solar drone mapping to Australia for the first ...

ZIHAN (FRED) ZHANG | 2 DAYS AGO

- Design for reuse.
- Availability of spare parts.
- Innovate for more efficient testing, particularly at utility-scale.
 - ✓ *Drone-based thermography.*
 - ✓ *In-field PL/EL*
 - ✓ *Machine learning for sorting the decommissioned PV modules*
- Decommission, collection and transportation efficiency.



Economics

Market?

- Market do exist.
 - ❖ Mostly irregulated and traded *via* Social media and in Europe like PVxchange.
- Total 1GWp/year is estimated to trade in 2020 (Europe only 300 MW/year).
- Export of PV panels to low-and middle-income countries.
 - ❖ *Unauthorize export of decommissioned modules to low-income countries increase the risk of “re-location of waste”.*
- Price competitiveness with new modules.

Profitability?

- Cost = decommission + collection + transportation + testing +
 - ❖ Financial incentives for reuse PV.
 - ❖ Improved warranties.
 - ❖ Imposed landfill ban (cost).



Reuse business areas

- ❖ Not worth it
- ❖ Not as good as new
- ❖ Is it reliable?
- ❖ How can I trust?
- ❖ Safety risk? Fire risk?

Organisations	Continent	Collection	Wholesale	Retail	Testing	Refurbishment	Integration
ScalingPSS*	Europe						✓
REScoop PV*	Europe						✓
Goodsun	North America	✓		✓			✓
Fabtech solar solutions	North America	✓		✓	✓	✓	
My second life solar	Australia	✓			✓		✓
EnergyBin	North America		✓		✓	✓	
SanTan Solar	North America			✓			
SecondSol	Europe		✓		✓	✓	
PVXchange	Europe		✓				
PVLab	Australia				✓	✓	
Blue-tribe	Australia		✓		✓	✓	✓



Market identification

Energy Poverty:

“Lack of adequate, affordable, reliable, quality, safe and environmentally sound energy services”

Scenarios:

- ❖ New PV modules are cheaper, high-performing and maybe lasting for 25 years.
- ❖ *Reuse PV modules are cheaper, slightly low-performing and may also last for 15+ years.*



REUSING SOLAR EQUIPMENT TO CREATE THE GREATEST VALUE FOR THOSE WITH THE GREATEST NEED

The Equitable Solar Solutions™ team works to create more just and sustainable energy solutions that benefit disadvantaged communities through reuse of solar energy systems.

**Research gap: Identify market.
: Market creation.**



Pilot project

PV Solar Stewardship Pilot:



Smart Energy council and Queensland gov.

- ❖ 1.2 millions of modules per year
 - 40-50% are shipped to either Africa or pacific island.
- ❖ World's largest test of decommissioned modules (5000).
- ❖ Systematic tracking of modules movement, cost, efficiency etc.

- ✓ **Collection:** Installers drop at designated points.
- ✓ **Centralisation:** SEC collects panels and transports them to a central location.
- ✓ **Recycling:** 85% of the panels are sent to various recycling centres.
- ✓ **Re-use Testing:** 15% of the panels are tested in certified laboratories.

In Europe: **Circusol:** 15 partners from 8 different countries



Conclusions

- ❖ End-of-life Management of Si PV?
 - ❖ No landfill
 - ❖ Reuse before recycle (if possible)
- ❖ What is PV reuse?
 - ❖ Reinstallation of decommissioned PV modules in other locations after appropriate quality control.
 - ❖ Reuse of modules \neq reuse of parts
 - ❖ Reuse of whole BOS.
- ❖ Current status of modules reuse?
 - ❖ Irregulated market
 - ❖ Developing testing protocols
 - ❖ Certification
 - ❖ Some business operation





Thank you for your attention!!!!

rabin.basnet@anu.edu.au

Michelle McCann
Laura Jones
Marco Ernst



Australian
National
University



**Circular PV
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