Circusol

Circular Business Models for the Solar Power Industry

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement 776680.

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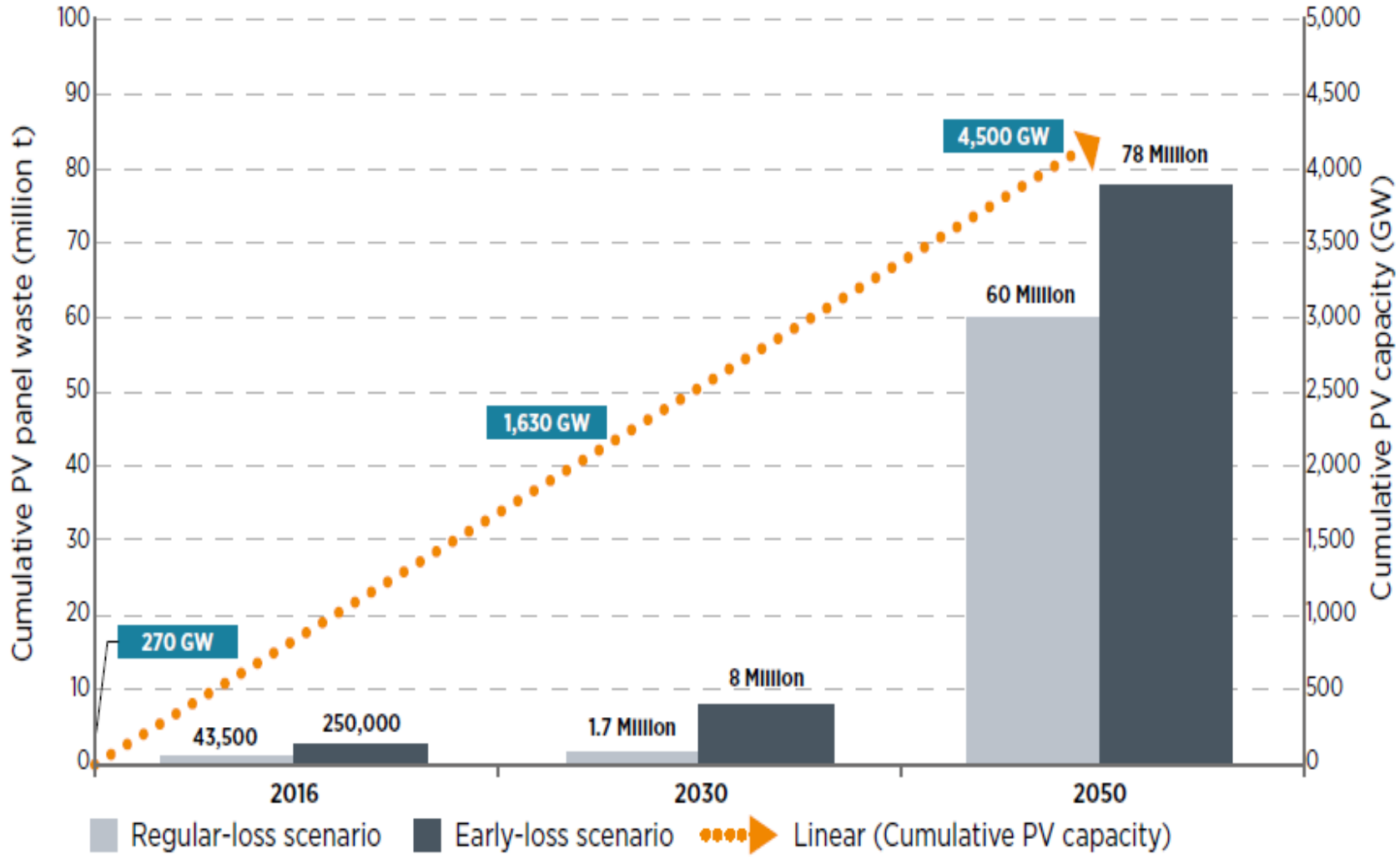
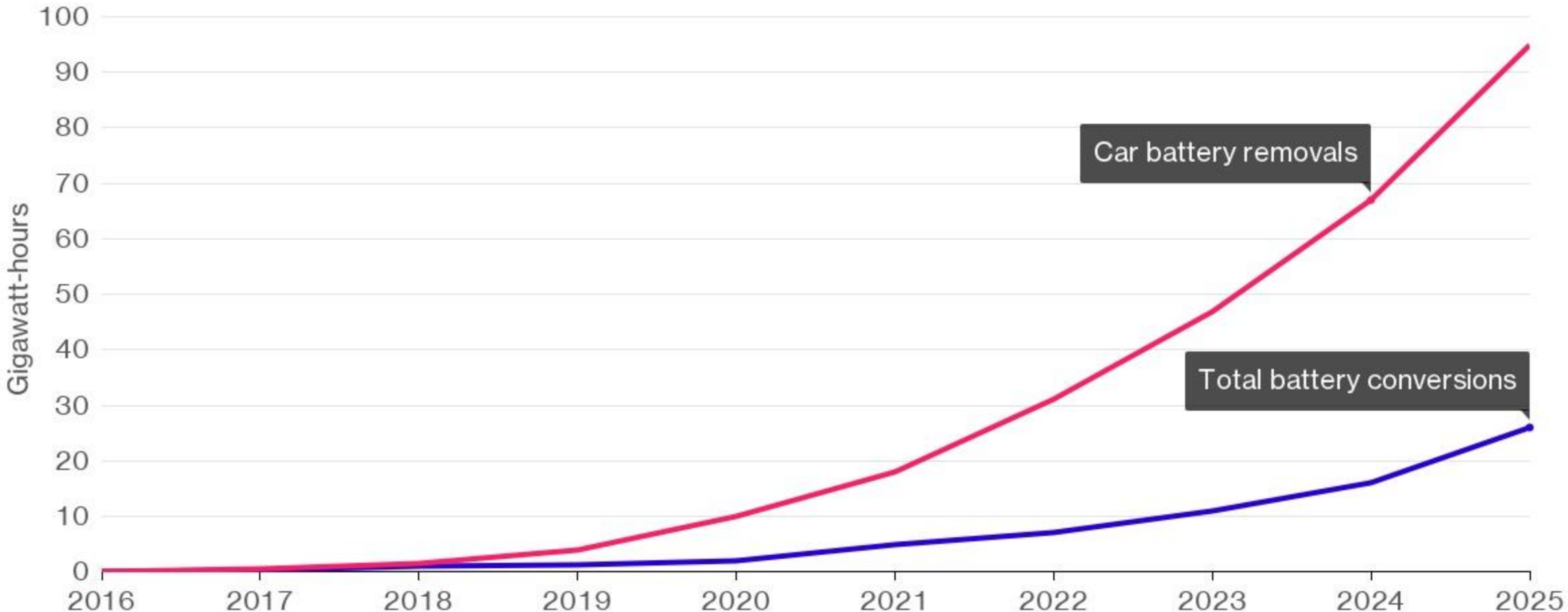
Global PV waste projections 2016-2050



Source: IRENA/IEAPVPS, June 2016

Plenty of Old EV Batteries Coming Soon

Can be converted to home energy storage



Source: Bloomberg New Energy Finance

Bloomberg

BY 2030...

8 million

tons of PV

WILL BE DISCARDED AS "WASTE"

2 million

old batteries

WILL BE REMOVED FROM EV

13 GW

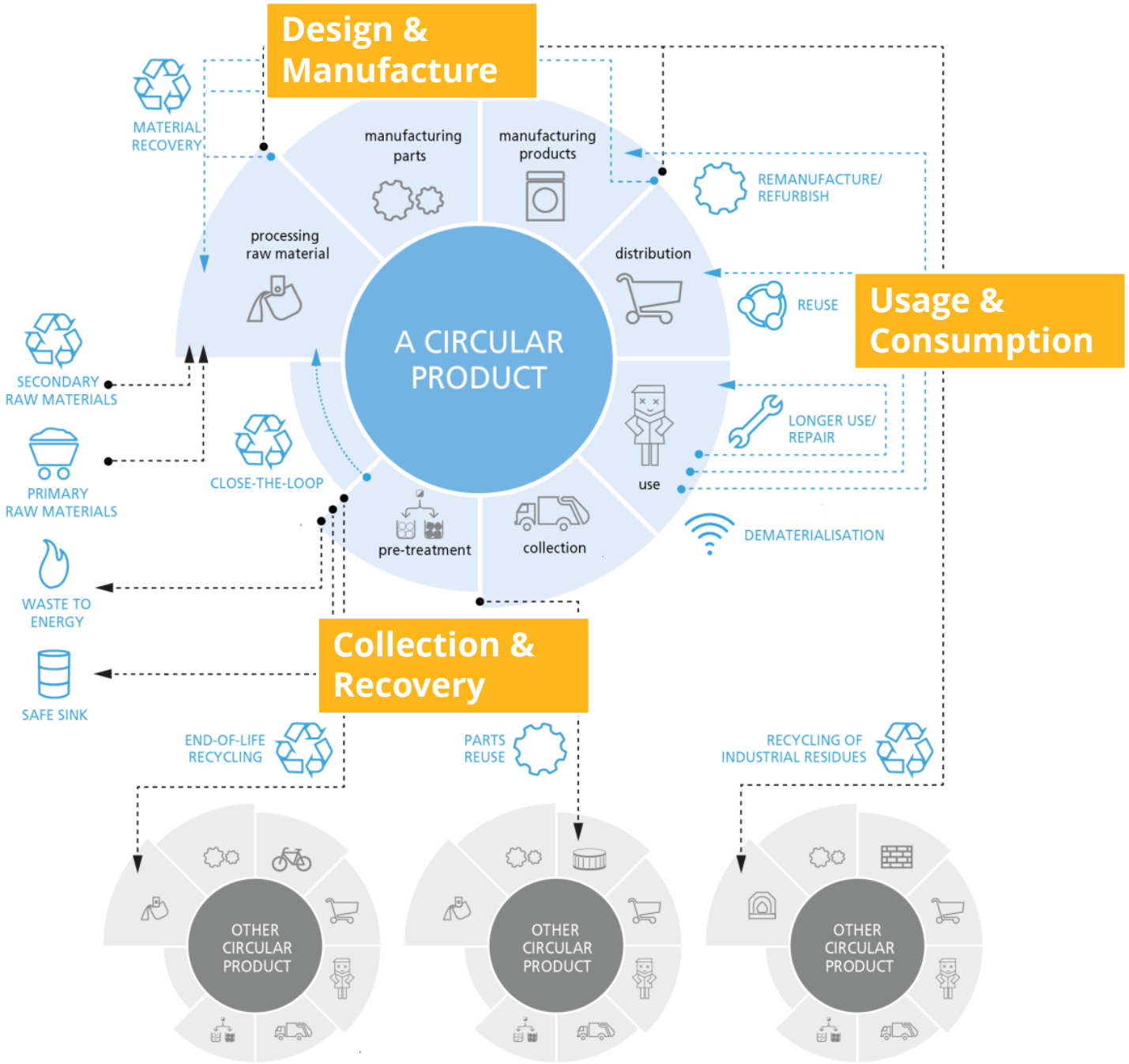
solar power for EU

CAN BE PROVIDED BY SECOND-LIFE PV

25 GWh

storage capacity for renewable energy

CAN BE PROVIDED BY SECOND-LIFE BATTERIES



CIRCULAR ECONOMY

involves ALL phases in product life cycle.

aims to unite environmentalists and economists.

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PRODUCT SERVICE SYSTEMS (PSS)

"Tangible products and intangible services designed and combined so that they jointly are capable of fulfilling specific customer needs."

— U. Tischner et.al.(2002)

Solar power industry is familiar with PSS:

- PV leasing
- Purchase

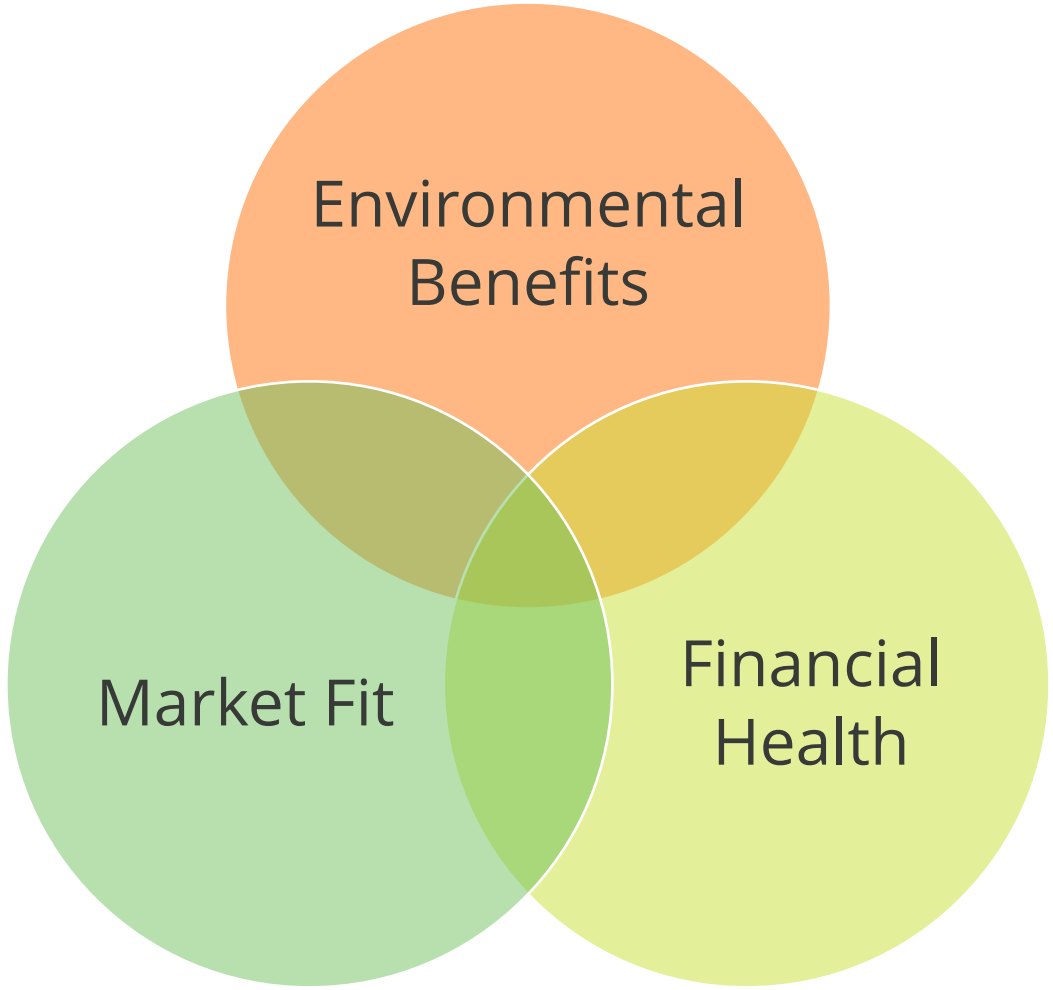
SolarCity

sunrun

SUNGEVITY

PSS has been the growth engine of US residential PV market

How can PSS deliver triple-win, for the end-user, the firm and the environment?



CIRCUSOL aims to turn solar power into a spearhead sector in demonstrating a path driven by systemic PSS towards a circular economy in Europe.

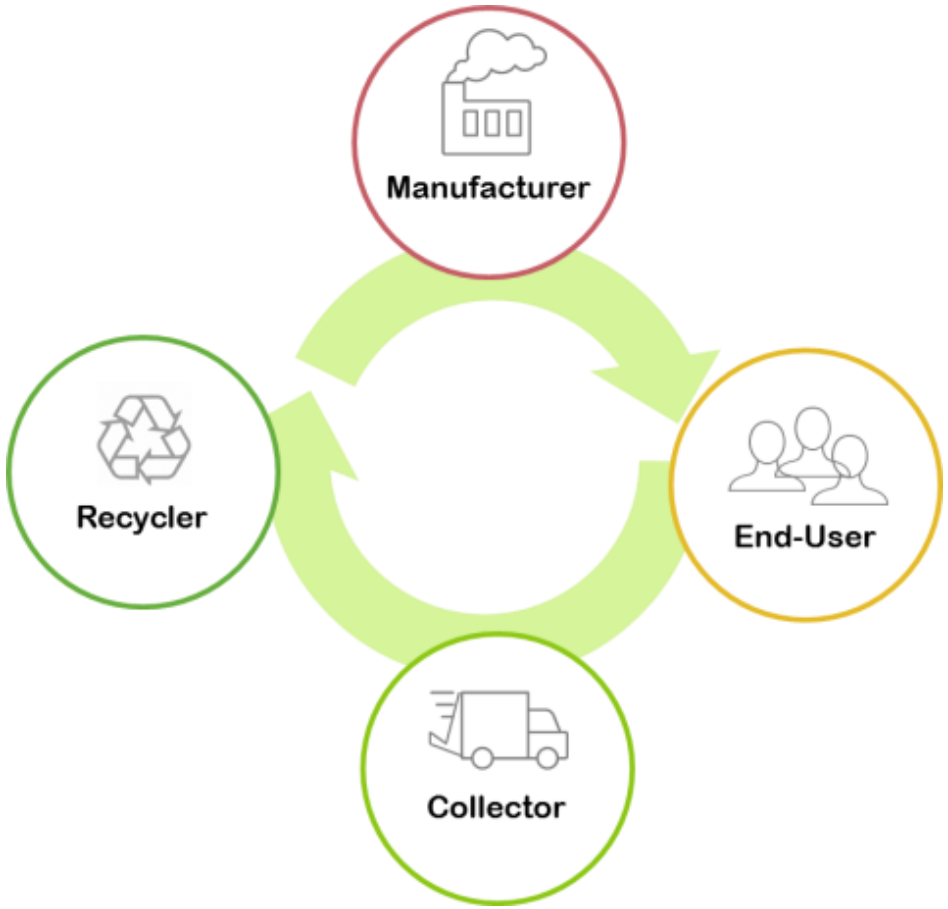
CIRCUSOL in Numbers

EC funding €7M

Jun 2018
—
May 2022

15 partners
7 countries

5 large-scale demonstrators



RECYCLING

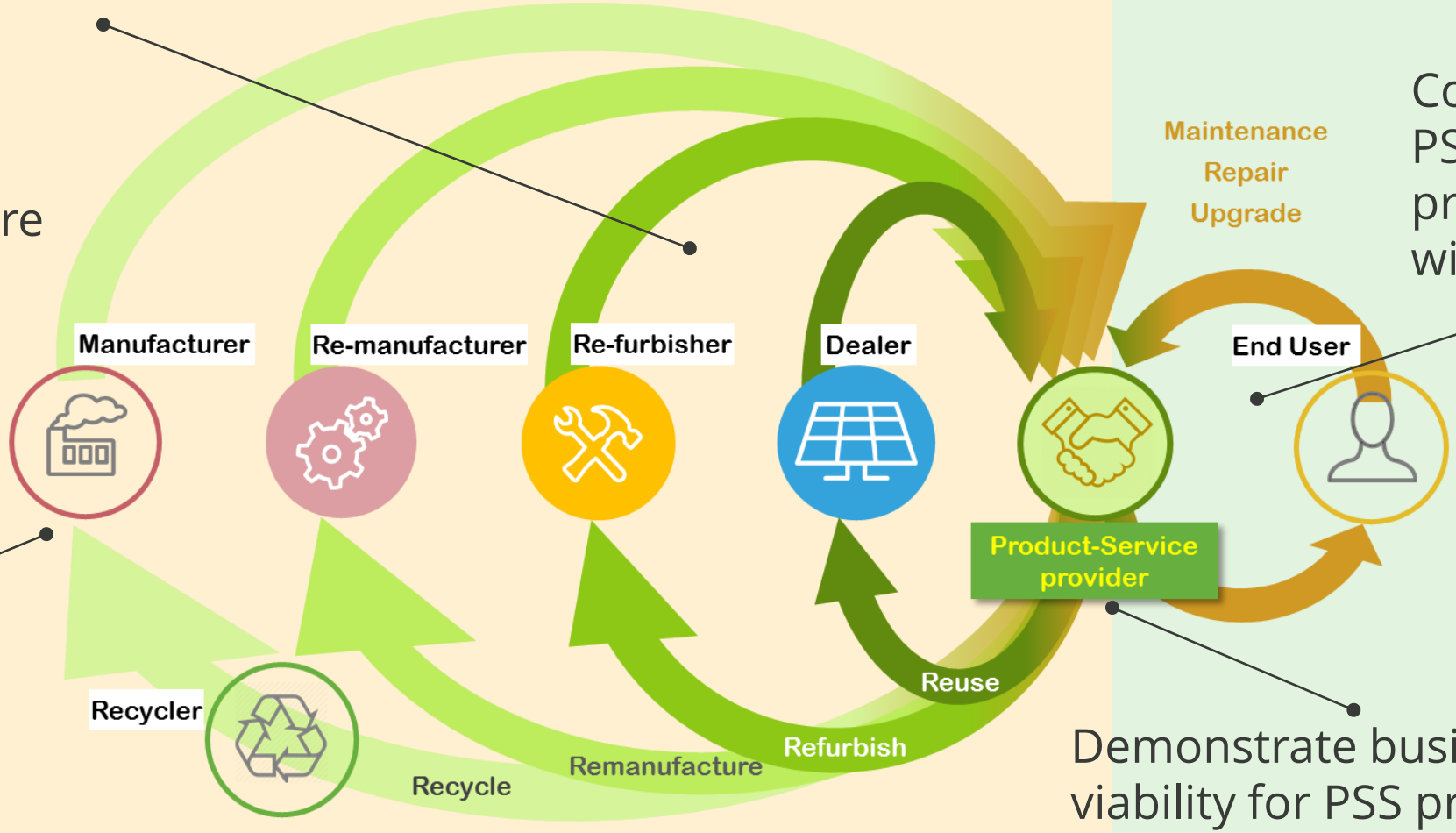
Is the ultimate circular path;

But it should not be the only and default path.

The most environmentally friendly and economical paths should be prioritized.

Develop "second-life" paths — re-use, refurbish, remanufacture

Co-create solar PSS value propositions with end-users



Incentivize "design for circularity"

Demonstrate business viability for PSS providers (and other actors)

Circular PSS Model = Circular Product Management + Value-added Product-Service

What to expect

1. **Cost-effective labelling and certification protocols for second-life PV modules and batteries**
2. **Real-life demonstrators with second-life PV/battery installed under PSS contracts**
3. **Business cases for circular product design (PV)**
4. **Circular business innovation methodologies for broader use in business/academia, and policy recommendations**

Market segment

Scale

Cloverleaf
Storage-as-a-service, Commercial

Waasland Co-housing
Solar service, Residential

SecondSun4grid
Energy management service, Utility

ScalingPSS
Scaling process, Residential

REScoop PV
Regional replication, Residential

Demonstrators

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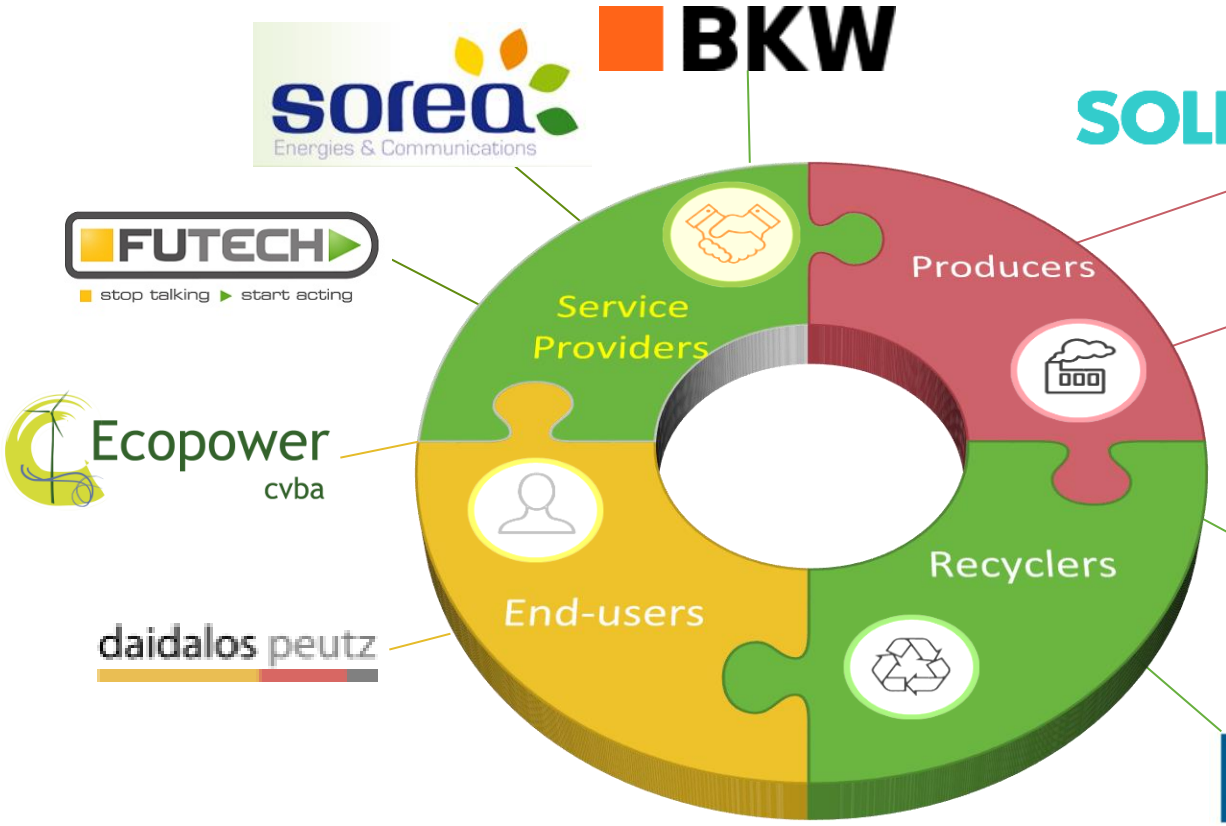
Meet the partners



soreq Energies & Communications

BKW

SOLITEK

FUTECH
stop talking ▶ start acting

SNAM
FLORIDIENNE

Ecopower
cvba

ASSOCIATION PV CYCLE

daidalos peutz

LOSER Chemie

Academia

Bern University of Applied Sciences

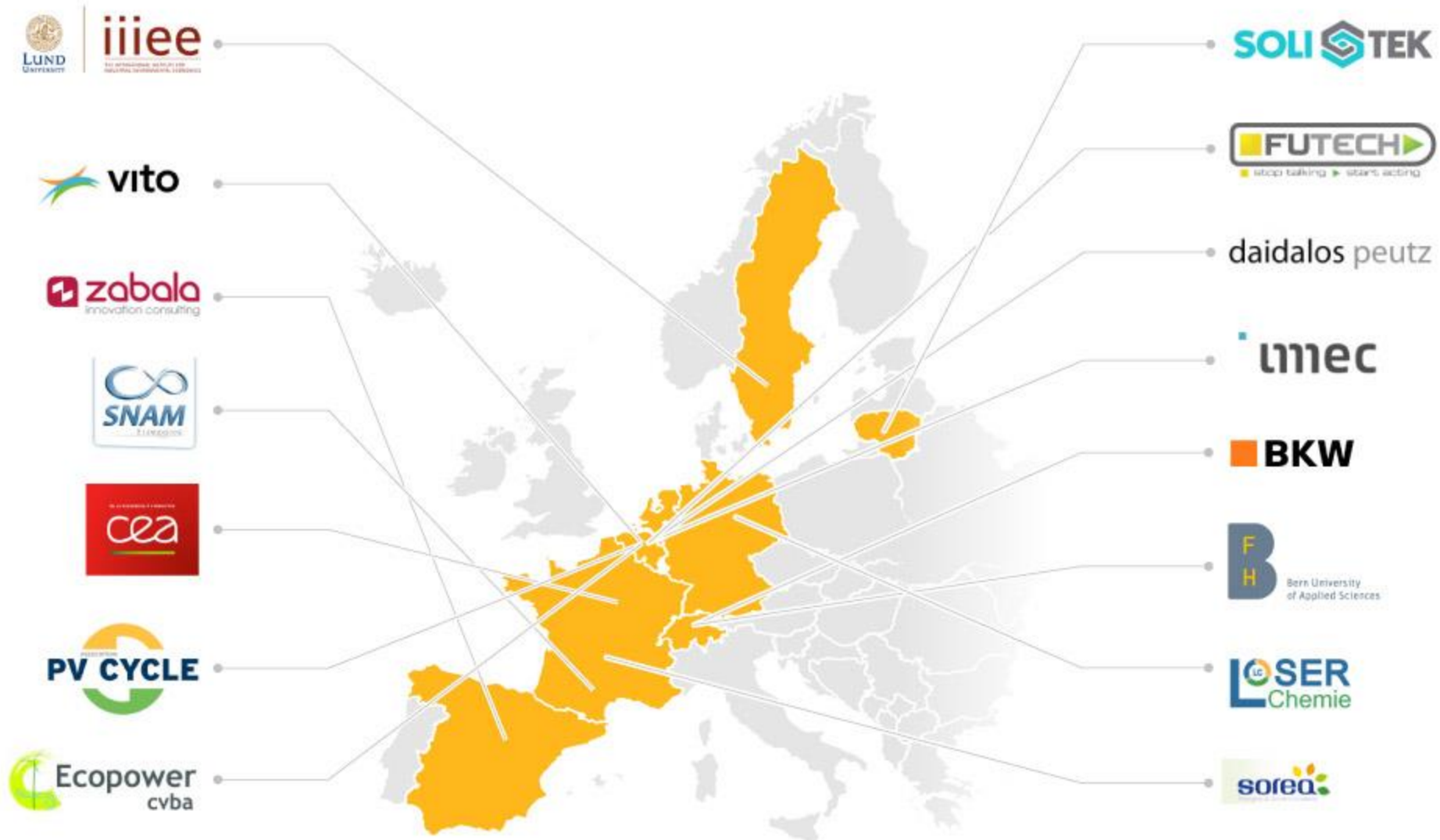
LUND UNIVERSITY

vito
vision on technology

cea

imec
embracing a better life

zabala
innovation consulting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PV CYCLE
Ecopower cvba
SOLI TEK
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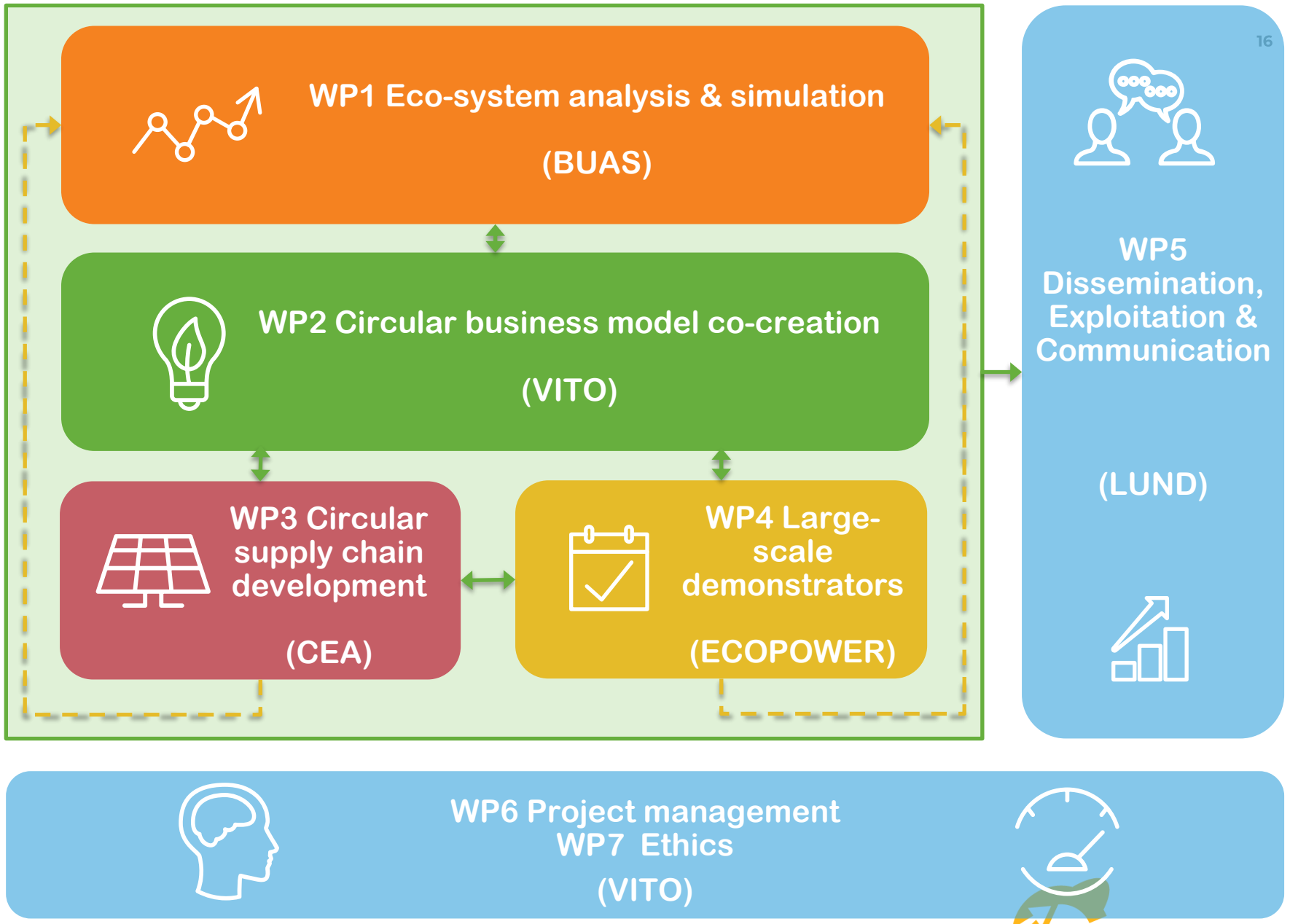
stop talking ▶ start acting
daidalos peutz
imec
BKW
FH
Bern University of Applied Sciences
LOSER Chemie
sorea

Work Packages



T3.1 Business impact of PV circular design report

2 publications:

Tsanakas, Ioannis (John) & van der Heide, Arvid & Radavičius, Tadas & Denafas, Julius & Lemaire, Elisabeth & Wang, Ke & Poortmans, J. & Voroshazi, E.. (2019). **Towards a circular supply chain for PV modules: Review of today's challenges in PV recycling, refurbishment and re-certification**. Progress in Photovoltaics: Research and Applications. 28. 10.1002/pip.3193.

Radavičius, T.; van der Heide, A.; Palitzsch, W.; Rommens, T.; Denafas, J.; Tvaronavičienė, M. 2021. **Circular solar industry supply chain through product technological design changes**, *Insights into Regional Development* 3(3): 10-30. https://doi.org/10.9770/IRD.2021.3.3(1)

First article

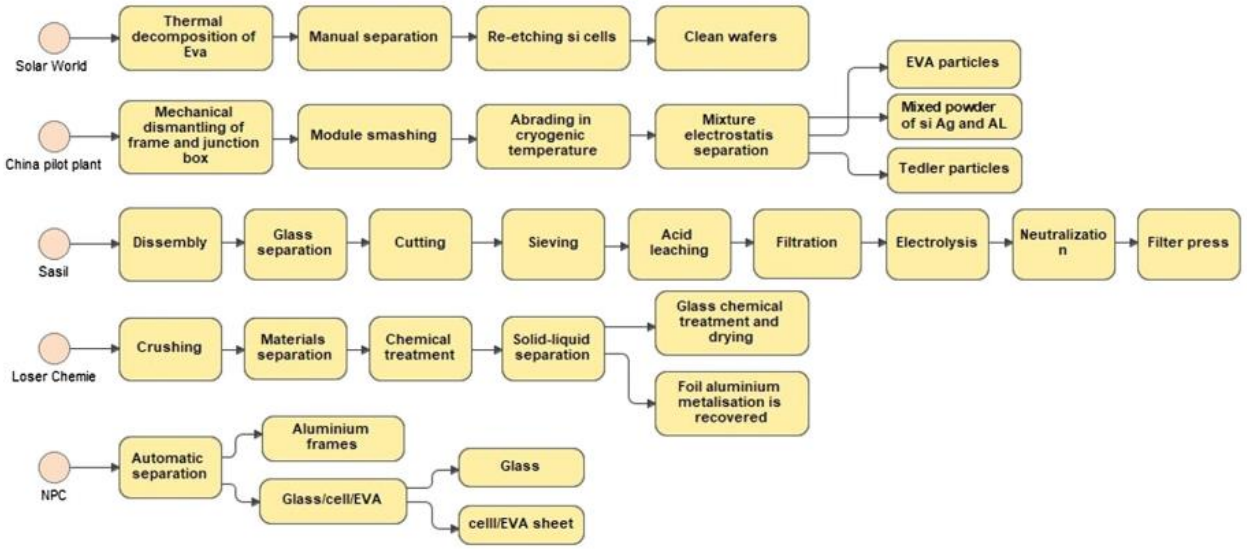


FIGURE 3 Overview of the different c-Si PV recycling process steps and workflows applied by key actors [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 1 Breakdown list of c-Si PV components/materials recovered throughout the recycling schemes of Sasil and NPC, and directed towards second-life, further recycling or disposal streams.

Material	Sasil	NPC
Aluminium	Towards secondary aluminium production	Traded to aluminium recycler
Copper	Traded to copper recycler	Cell sheet is traded to refinery industry
Glass	Glass culets can be used as a substitute or raw material for packaging	Traded to glass recycler for glass wool
Semiconductor (Silicon)	Used as metallurgical-grade silicon, metal subsidy	Cell sheet is traded to refinery industry
Silver	Towards secondary silver production	Cell sheet is traded to refinery industry where silver is extracted
Cables	Traded to copper recycler	Traded to copper recycler
EVA	Incinerated	Cell sheet is traded to refinery industry
Contaminated glass	Disposal in landfill	No contaminated glass during NPC process
Fly ash (hazardous waste)	Disposal in special landfill	Traded to refinery industry that takes care of hazardous waste
Liquid waste	Contains metallic residue; disposal in special landfill	No liquid waste during NPC process
Sludge (hazardous waste)	Contains metallic residue; disposal in special landfill	No sludge during NPC process

First article

However, with a significantly higher number of PV installations and modules expected to reach end-of-life, further R&D challenges will emerge towards the need for

- even higher recovery/recycling ratios;
- cost-efficient and environmentally friendly processes; and
- recovery of higher grade, quality/value materials and/or materials for PV re-manufacturing or re-use (second-life PV).

Finally, from a business/market point of view, challenges (thus, opportunities) on PV recycling are mostly associated with:

- upscaling of PV recycling operations and their optimization (i.e. mass-treatment, on-site processing);
- streamlining collection-transportation networks and global-scale reverse logistics;
- ensuring operational viability (need for sufficient PV waste, i.e. bankability); and
- implementation of sustainable and circular business models, namely towards re-use or second-life PV.

Second article

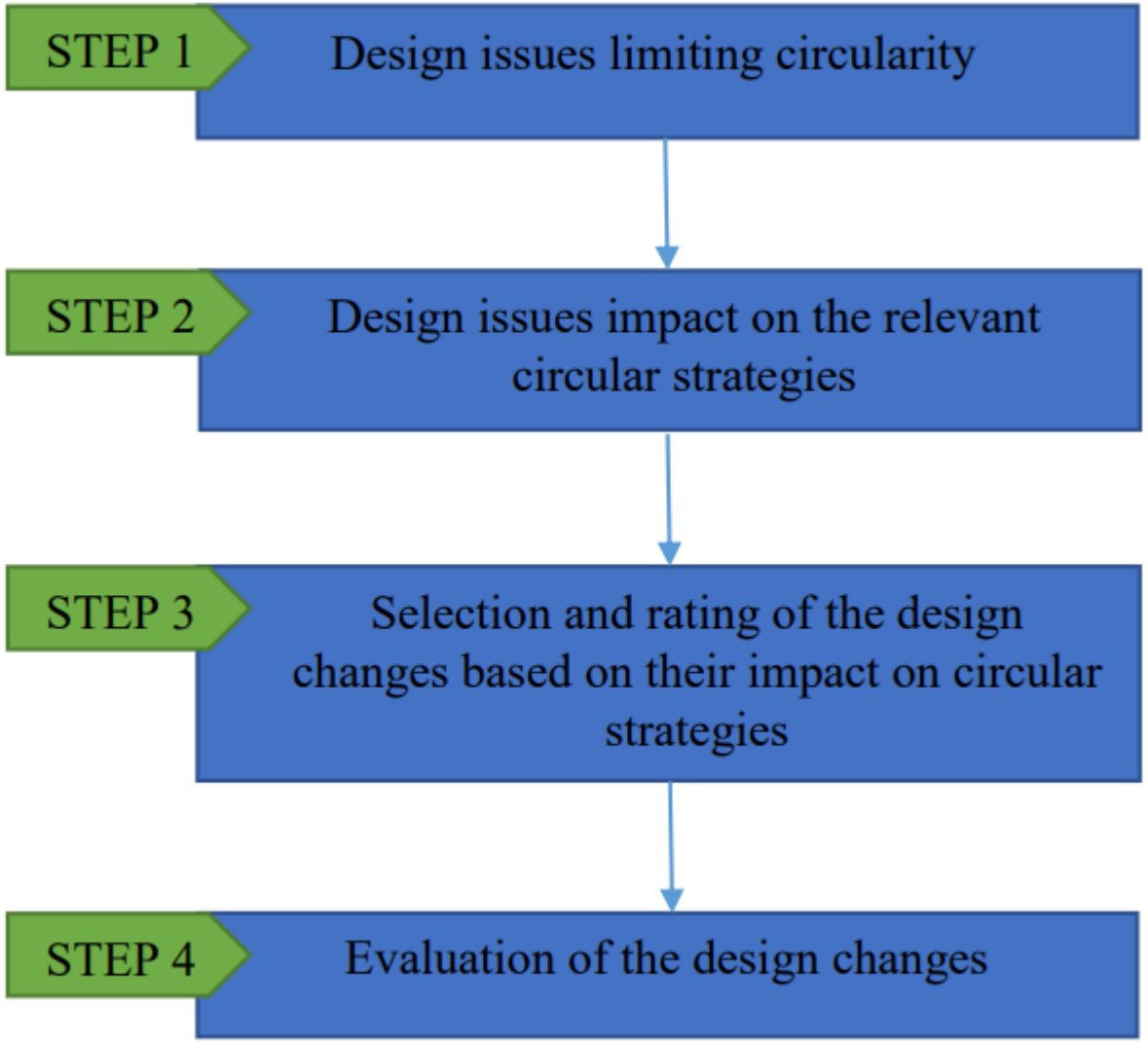


Fig. 1. Product circularity improvement' steps

Second article

Table 2. Design issues impact on circularity strategies

Current design issue of the solar panel	Impact on recycling	Impact on re-usability	Impact on repairing and refurbishment
Sandwich structure	Requires sophisticated and costly processes to recover high quality materials. Dominant mechanical recycling processes in industry recovers low-quality materials.	Not possible to re-use solar cells as they cannot be recovered in-tact due to lamination of encapsulants and glasses/back sheet.	Not possible to repair solar cells.
Lack of traceability of panels and their materials	Recycling companies cannot assess the possibility of different EoL processes based on panel materials and components due to a non-existent database about panels. Difficult to make decisions about recycling facility establishment due to lack of information about panels and their compositions in specific regions/countries.	Difficult to evaluate solar panel re-usability potential due to lack of availability of information related to panel materials, components, technology, etc., which could allow evaluating its second-usage value, applications, and markets.	Lack of easily accessible information that would allow better repairability/refurbishment (manufacturer recommendations on repairing, components specifics, etc.).
Diversity of panels components and materials	Panel manufacturers introducing recyclable components or less toxic materials provides additional challenges for recycling companies to adapt their processes and adjust recovered materials management.	Different materials and components combinations require evaluation for second-hand markets (toxic materials content compatibility with local country, availability to recycle such panels in the country, etc.).	Different repairability feasibility based on panels composition.
Diversity of panels sizes	Different panels dimensions and weights influence logistics and recycling machinery line feasibility to recycle them.		
Diversity of panels	Glass/glass, glass/back sheet, thin films, and silicon panels can have different dedicated recycling processes. Future different types of panels could challenge recycling feasibility for high-value materials recovery.		

Source: made by the authors

Second article

Table 3. Comparison of design changes (source: made by the authors)

	Potential for Recycling	Potential for Re-use	Potential for Repair and Refurbishment	Required capital investment for the manufacturer	Change in solar panel BOM	Overall positive impact towards circularity
N.I.C.E encapsulation	High	High	High	High	Low	**High**
ECA	Low	medium	Low	Medium	Medium	**Medium**
Lead-free ribbons	Low	medium	Low	Low	Low	**Medium**
Fluorine-free back sheet	Medium	medium	Low	Low	Medium	**Medium**
RFID	Medium-High	High	High	Medium	Low	**High**

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