

PV sustainability and circular model in the PV value chain

PHOTORAMA – A circular model from concept to field experience

*PHOTORAMA - Photography process from the Lumières brothers -
Panoramic view enabling the full reproduction of the horizon*



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Organization : **CEA**



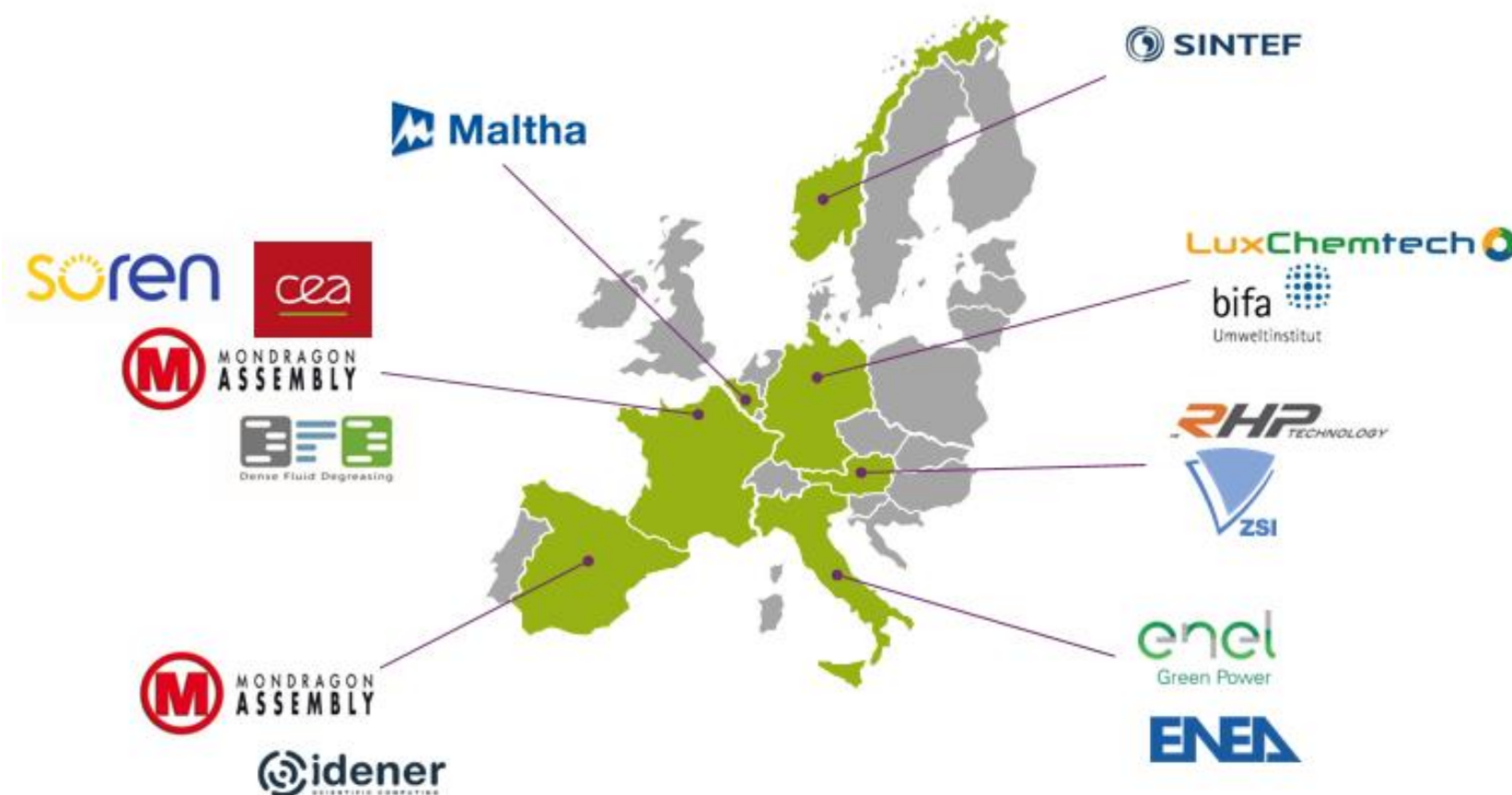
PHOtovoltaic waste management – advanced Technologies for recOvery & recycling of secondary RAW MAterials from end-of-life modules

H2020 project (May 2021 – April 2024)

Budget : 10,365,764.75 €

EC Contribution : 8,381,666.38 €

- 13 partners
- 8 work packages and 5 key objectives
- Set up of a full management Pilot Line



A circular economy across the photovoltaic value chain

“develop innovation leading to successful and competitive solutions to launch sustainable markets for secondary RM in Europe.”





Context & definitions

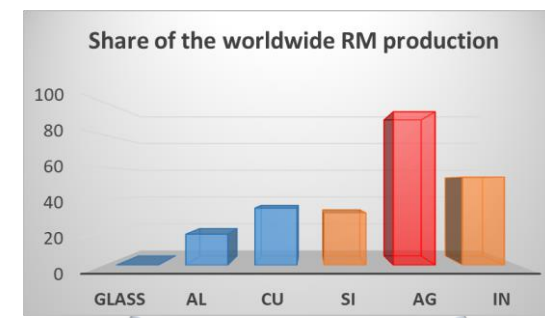
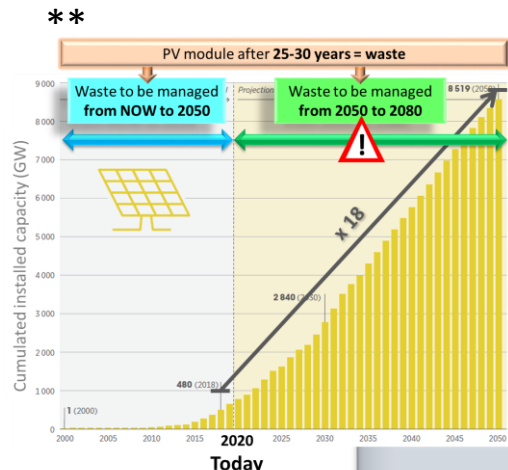


Our project

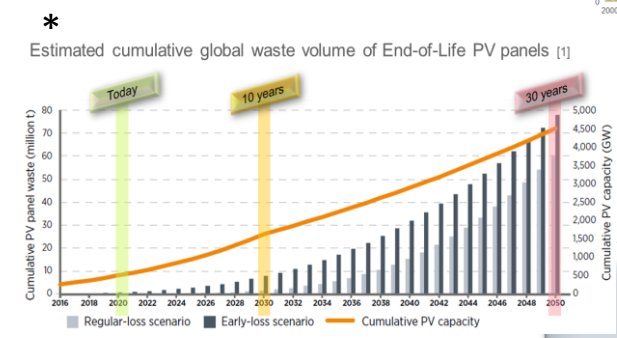
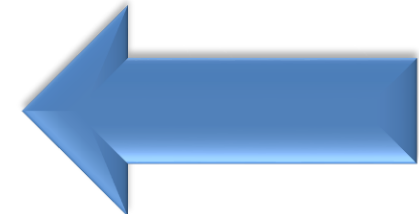


Perspectives

Why?



Sustainability



PV waste In the future

- 2,840 GW by 2030
- 8,519 GW by 2050

Raw materials Supply Chain

- Technological
- Environmental

Circular economy

- Manufacturing in progress + Ecodesign
- EoL → Weak spot

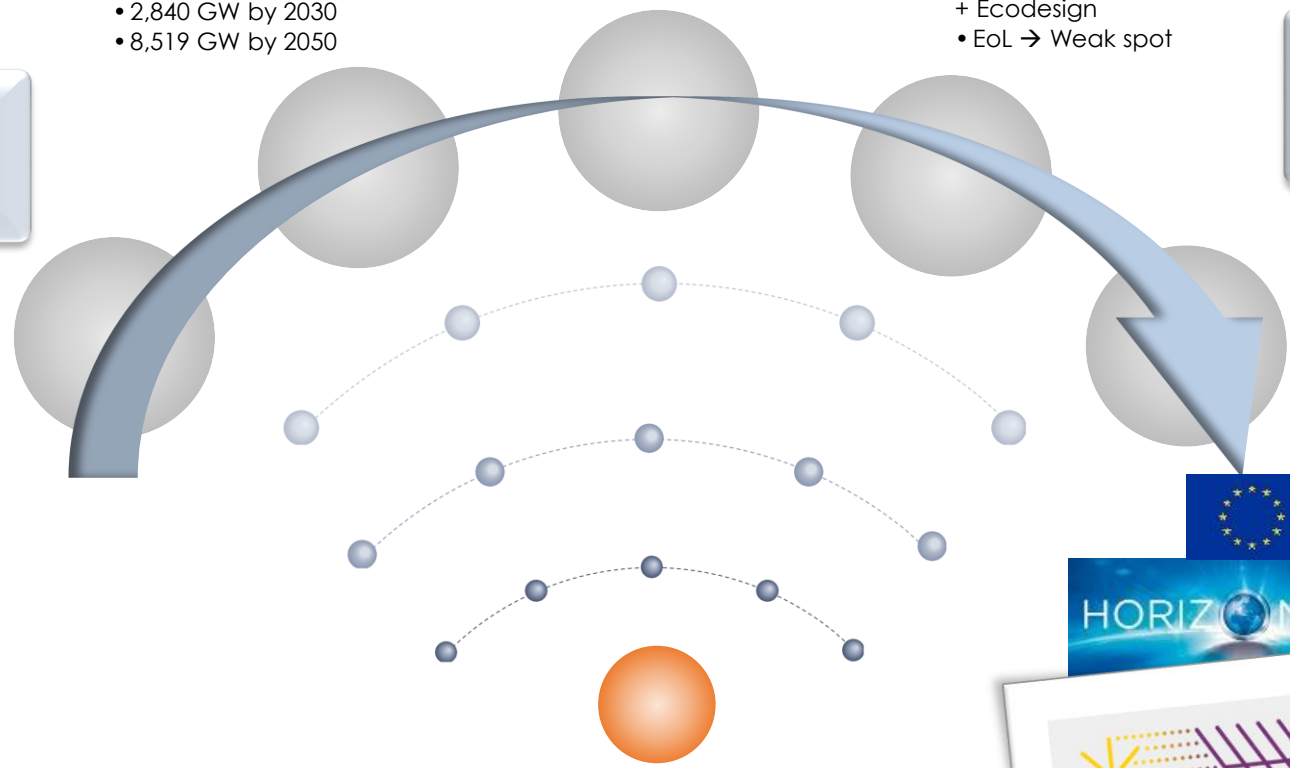
PV recycling Current practices

- Landfilling
- Shredding



PV waste NOW !

- 60-78 Mtons worldwide
- ~10 Mtons in Europe By 2050



* Source : IRENA & IEA-PVPS, End-of-Life Management: Solar Photovoltaic Panels, 2016
 ** Source : IRENA Report – “Future of solar photovoltaic”, 2019



This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 958223.

SUSTAINABILITY

What is it?

Sustainability vs “long term” focuses on meeting the needs of the present without compromising the ability of future generations to meet their needs. Sustainability concept made up of three pillars:

- ❖ Economic (profits)
- ❖ Environmental (planet)
- ❖ Social (people)



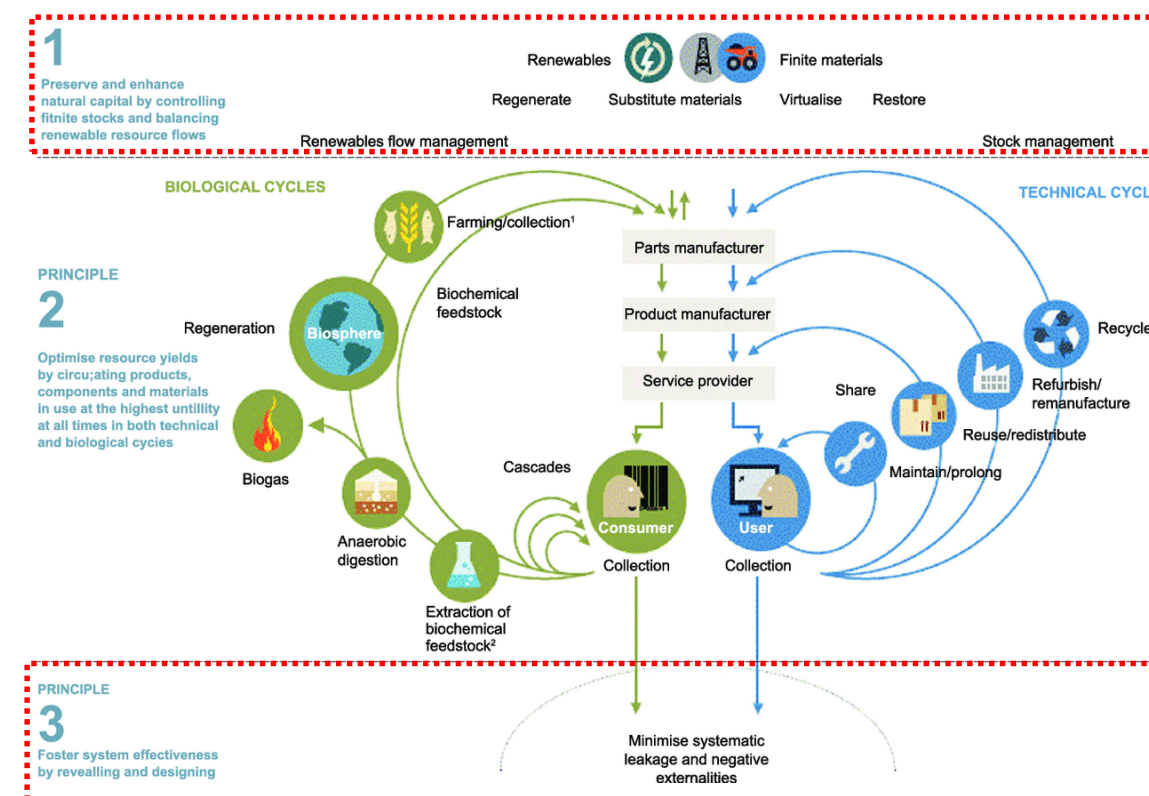
Source: United Nations



CIRCULAR ECONOMY

Restorative economy where all the actors in the value chain are dependent on each other to close the loop. Circular Economy concept made up of three pillars:

- ❖ Natural capital – design
- ❖ Resource circularity
- ❖ Systemic efficiency – eliminating externalities

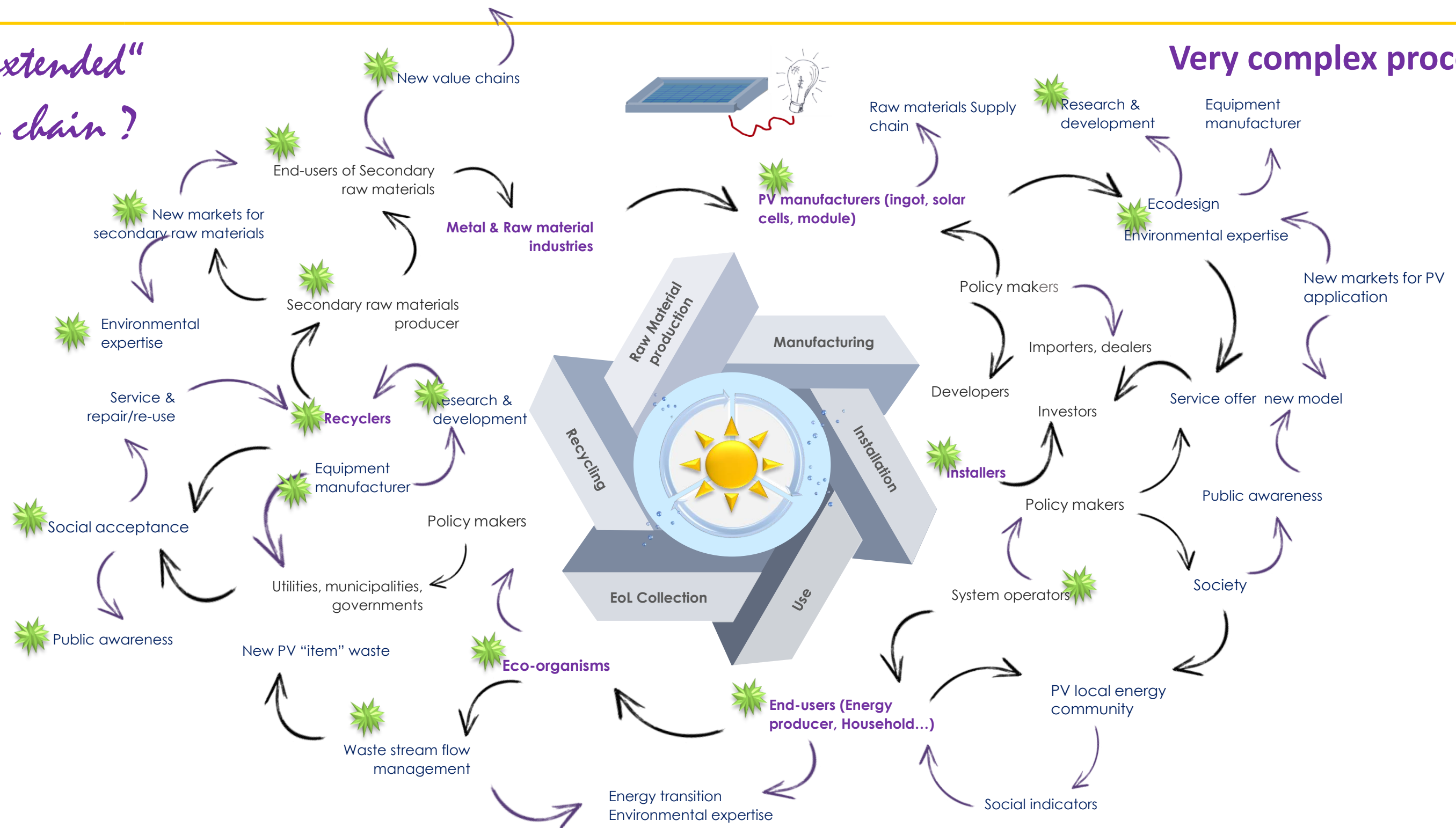


Source: Ellen MacArthur Foundation



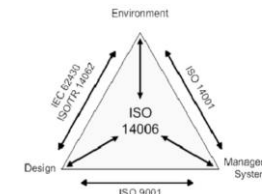
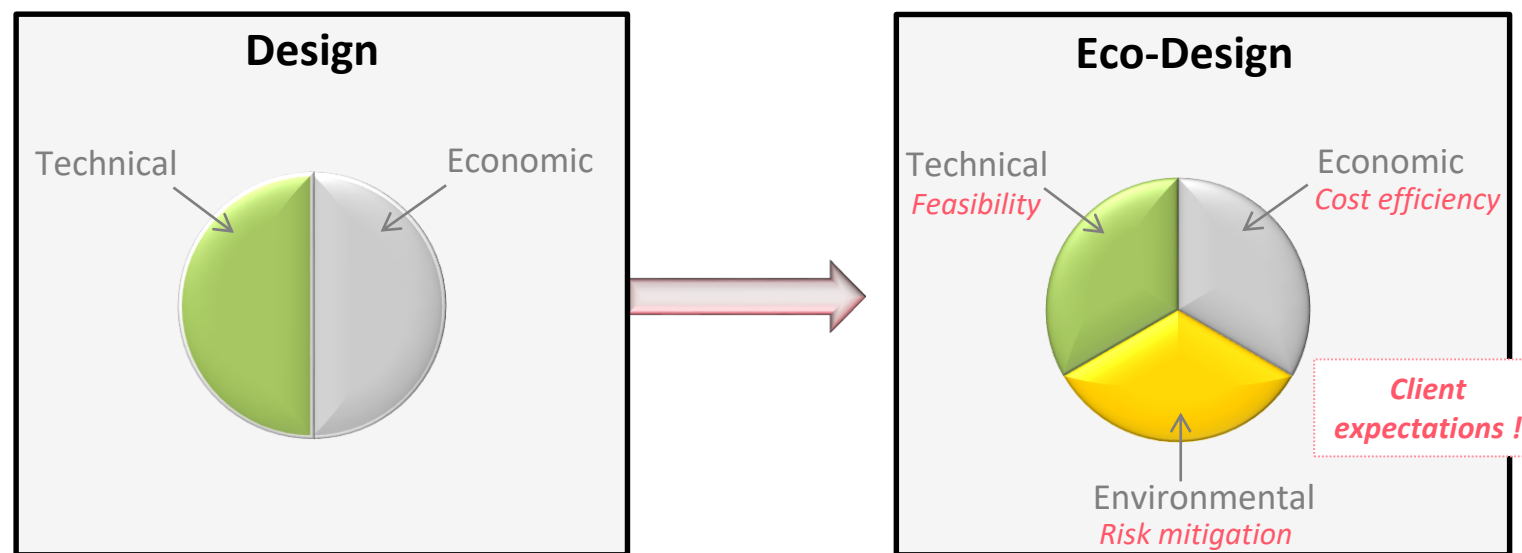
PV "extended" value chain?

Very complex process !



ECO-DESIGN

What is it ?



ISO 14006:2011 (revised by ISO 14006:2020)*
 “A systematic approach that considers the environmental aspects of the design and development process in order to reduce negative environmental impacts throughout the life cycle of a product”

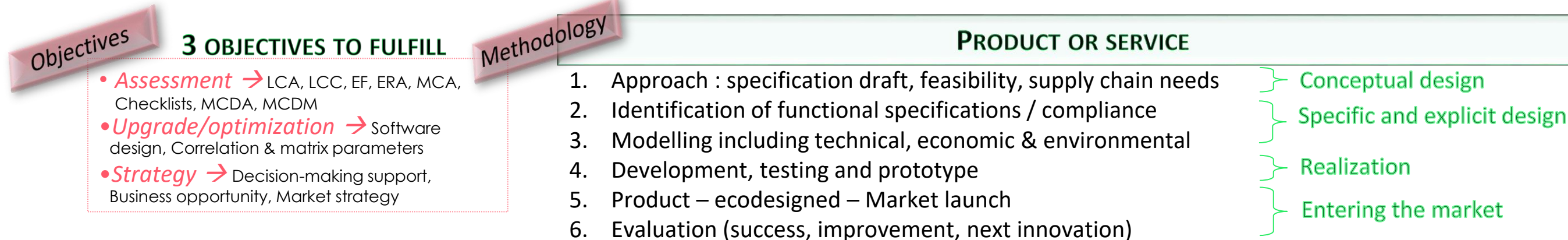
- Raw materials acquisition
- Design and development
- Manufacturing
- Delivery and installation
- Utilization (including reuse, maintenance, repair, reconditioning, refurbishment and modernization)
- End-of-life treatment
- Disposal

Directive 2009/125/EC

(under revision 2020)
 Article 2.23 - “Ecodesign means the integration of environmental aspects into product design with the aim of improving the environmental performances of the product throughout the its whole life cycle”
 * Introduction Section 17 “eco-design requirement should be established on the basis of technical, economic and environmental analysis.”

ECO-DESIGN

How does it work ?

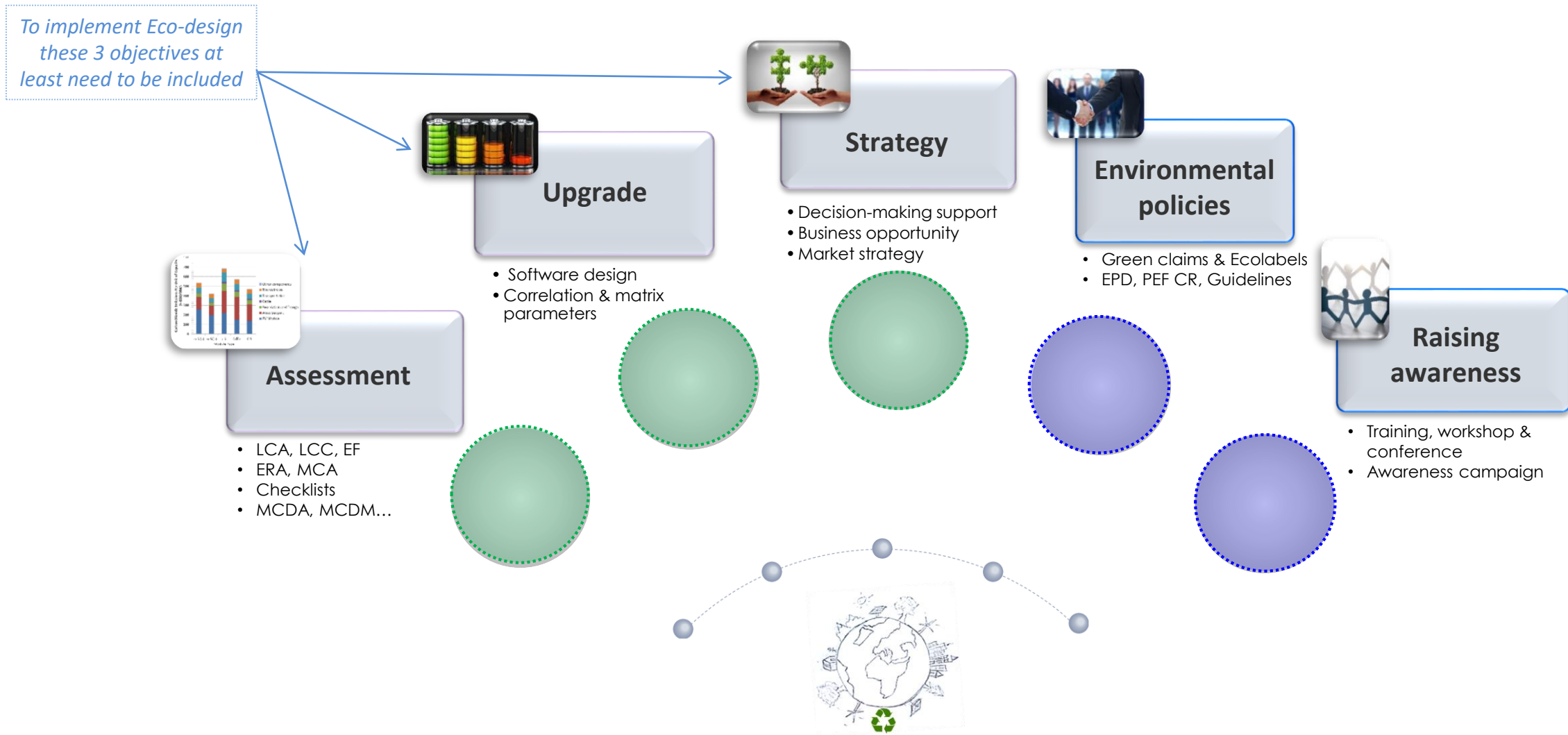


* ISO 14006 provides guidelines to assist organizations in establishing, documenting, implementing, maintaining and continually improving their management of ecodesign as part of an environmental management system (EMS).

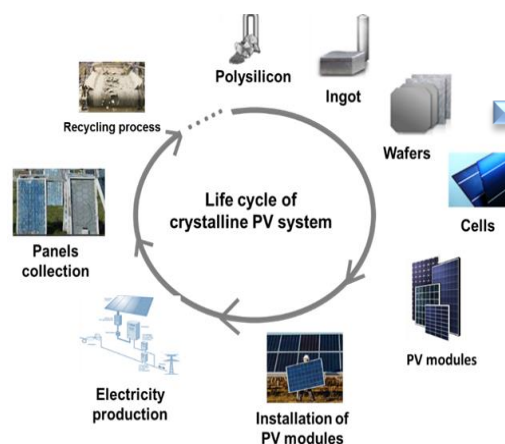


ECO-DESIGN

Which tools for which objectives?



ECO-DESIGN → *Targets & guidance*



PV life cycle thinking

- Raw material extraction for all the components
 - Production (purification, crystallization, wafering, cells, module assembling)
 - Installation (mounting structure, electrical components)
 - Use (operation & maintenance, control, repair, refurbishment)
 - End-of-Life management (collection, landfilling/storage or recycling, production of secondary raw materials)
- Including any transport needed at each step*

Main targets that to be considered:

- Design for life cycle EP
- Design for recycling
- Design for health & safety



Critical points to be addressed:

- Energy efficiency
- Materials (hazardous, depletion)
- End-of-Life management



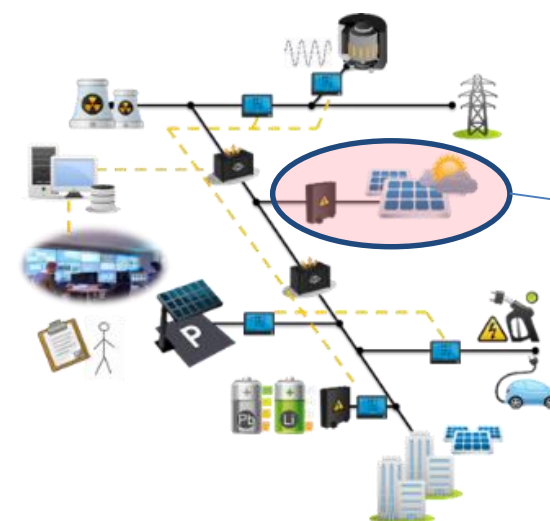
Success & relevance of the approach

→ Strongly depend on:

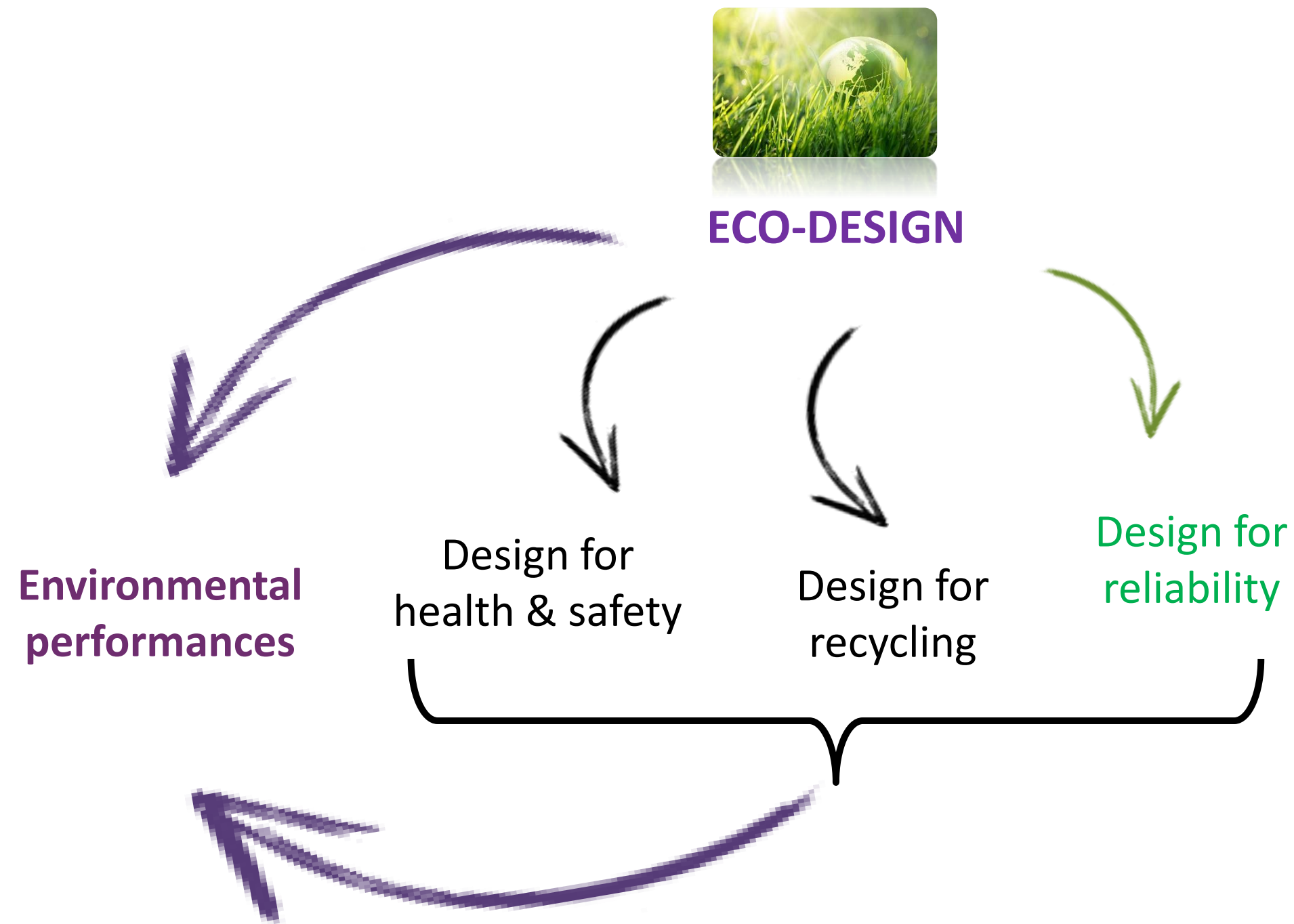
- ✧ Methodology & tools selected,
- ✧ Data quality over the life cycle
- ✧ Fulfilment of the 3 objectives
- ✧ Modelling matrix (tech./eco./env.)
- ✧ Compliance to conformity within the scope



At a product level



At system level
Installation level



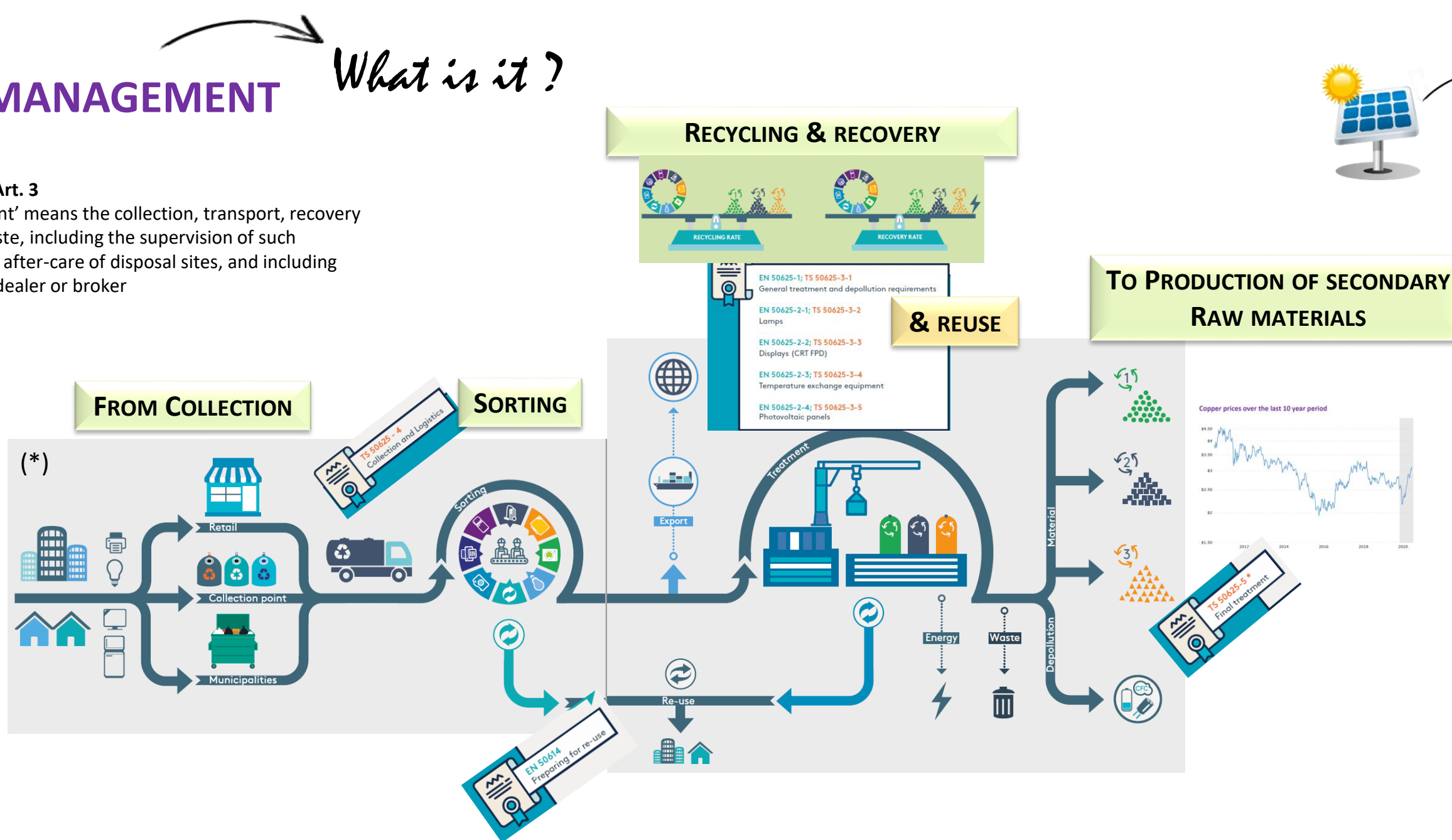
Design for
SUSTAINABILITY

WASTE MANAGEMENT

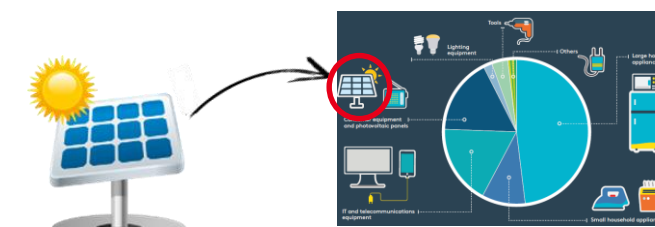
What is it?

(D) 2008/98/EC – Art. 3

‘Waste management’ means the collection, transport, recovery and disposal of waste, including the supervision of such operations and the after-care of disposal sites, and including actions taken as a dealer or broker



(D) 2012/19/EU



(*) https://www.cencenelec.eu/media/CEN-CENELEC/AreasOfWork/CEN-CENELEC_Topics/Environment%20and%20Sustainability/Quicklinks%20General/Documentation%20and%20Materials/weee-brochure.pdf



PV waste ?

WEEE 2012/19/UE (transposition 2014 member states) → Category 4 – PV equipment



Which kind of WEEE ?

→ Crystalline Silicon- based ~ 95% of the market → 1.6 to 2 m² including **4-5 metals** (+traces)

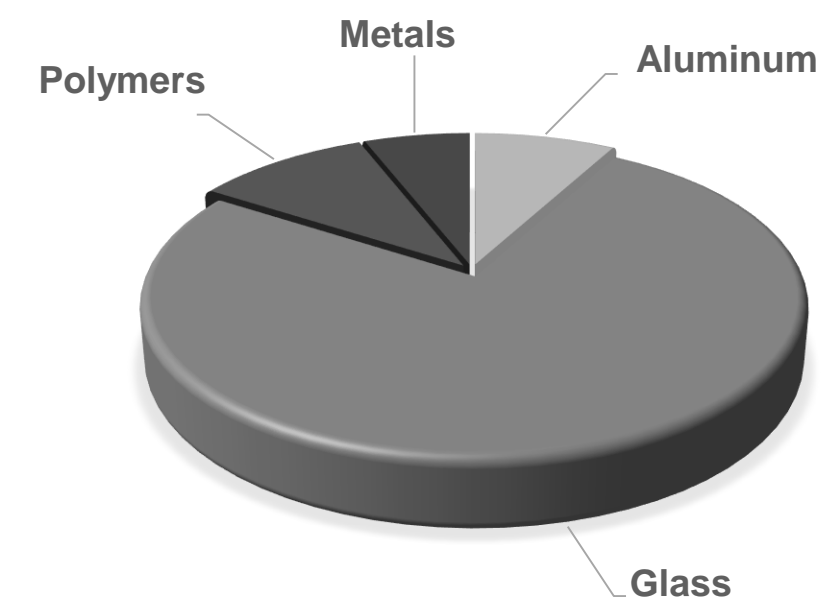
(+ Thin films (CdTe, Cl(G)S) ~ 5 % of the market amongst emerging technologies)

*Compared to a smartphone → ~0.00005 m² including up to **50 metals**

How much compared to WEEE stream ?

→ PV waste could exceed **10% of WEEE stream globally by 2050**

What's to be recovered ??



* Considering the world's population of 2017 assessed by the United Nations and an average power module at 300Wp



PV "extended" value chain?

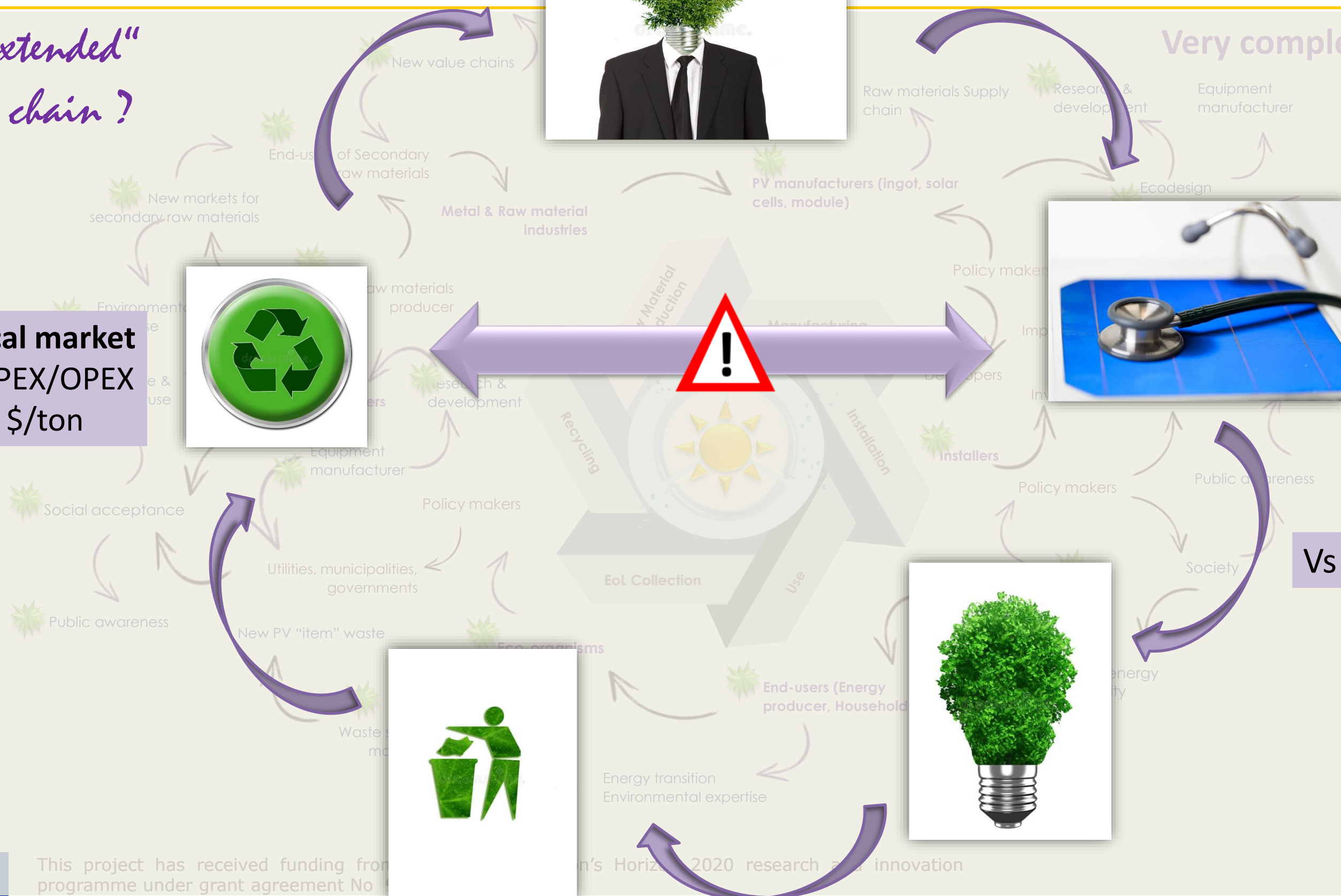
Very complex process !



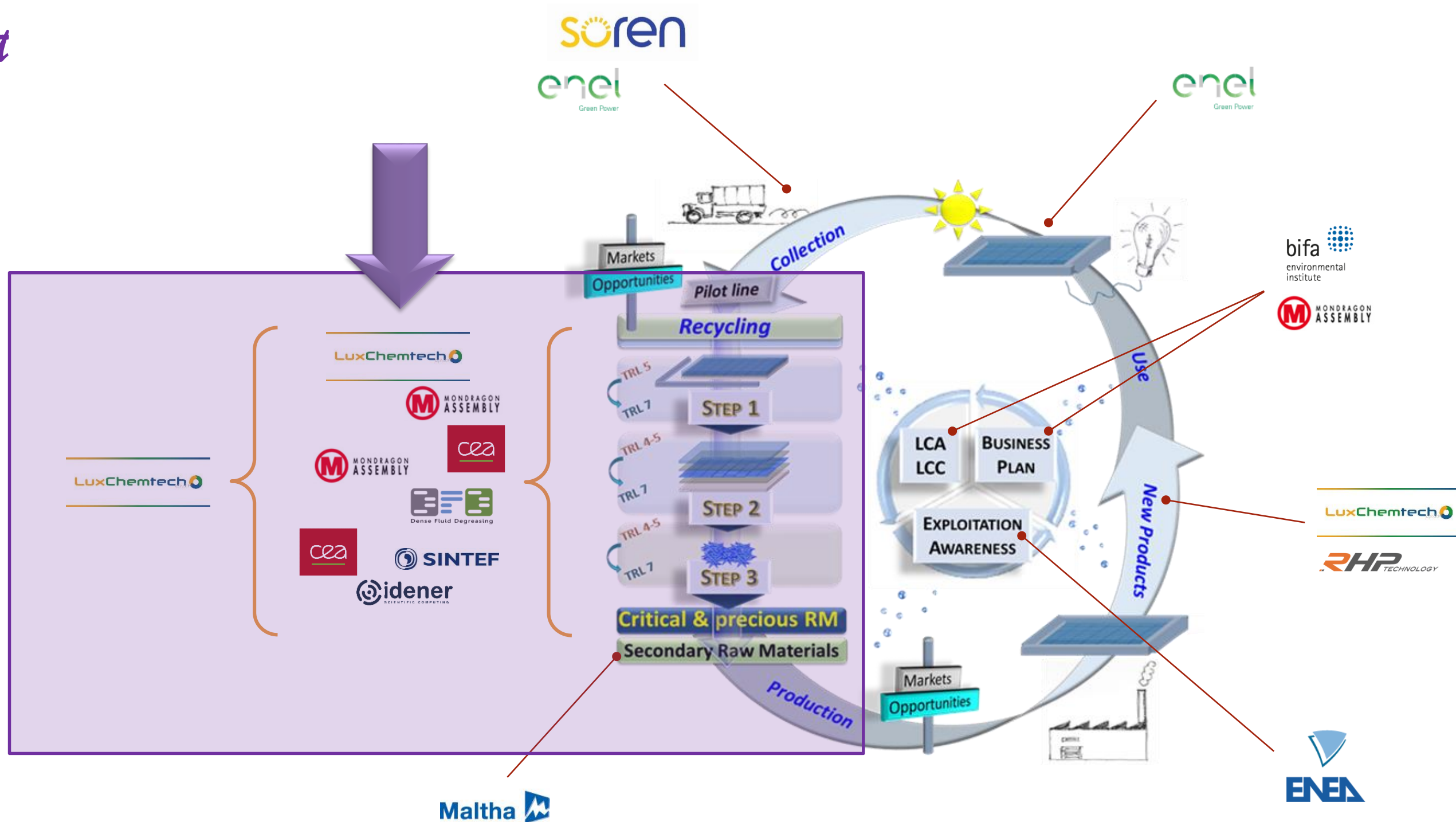
Local market
CAPEX/OPEX
\$/ton

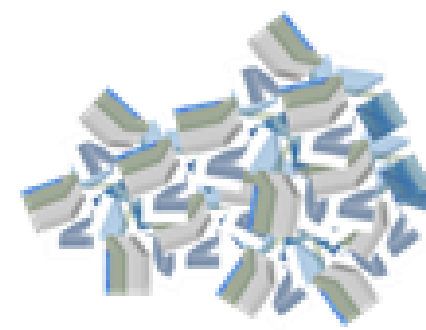
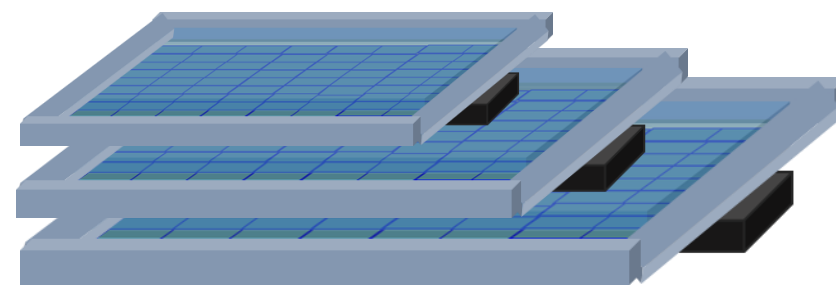
Global market
CAPEX/OPEX
\$/products

Vs ct\$/Wh



Our concept





c-Si & CI(G)S
waste stream

Our strategy

End of Life module

DISASSEMBLING

MATERIALS RECOVERY

Metals

Glass

Polymers

DELAMINATION

Step 1

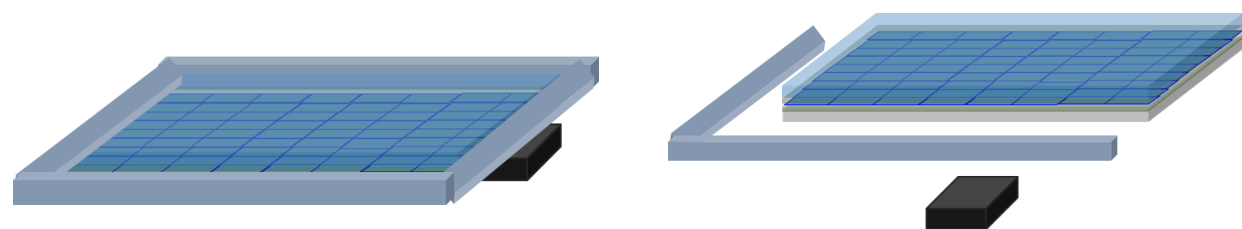
Step 2

Step 3



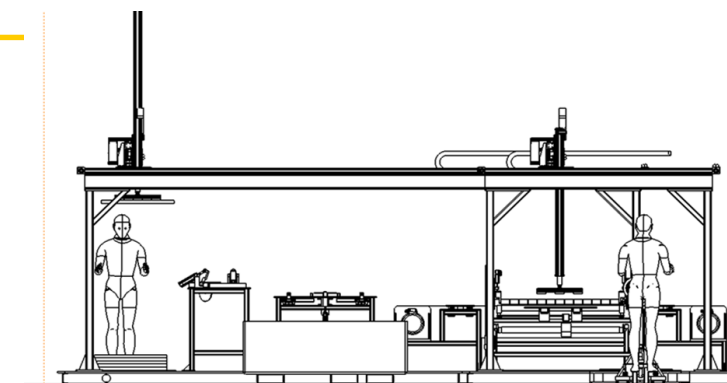
Step 1

DISASSEMBLING



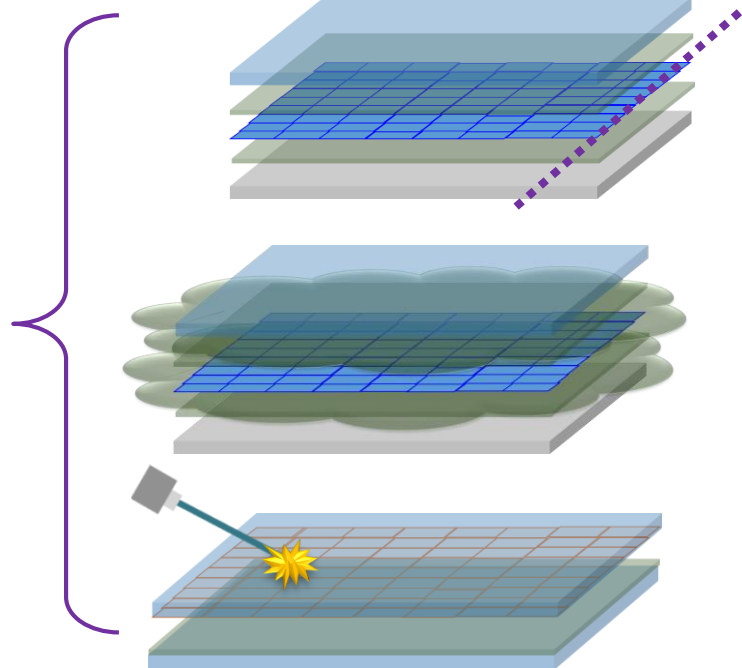
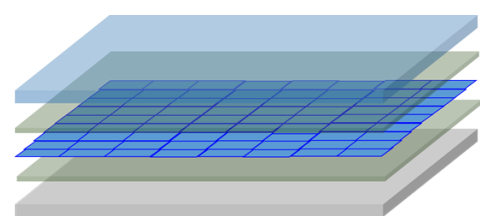
Disassembly of external components

Full-automation panels handling @1200tons/y
 - Removal of junction box (→ recovery others WEEE)
 - Removal of Al frame (→ metal refinery)
 Without breaking the devices



Step 2

DELAMINATION



Diamond wire cutting process

Mechanical delamination cutting through

- Intact glass sheet (recycling or re-use)
- Cells residues (for step 3)
- Polymer backsheet (energy fuel)

Super critical fluid process

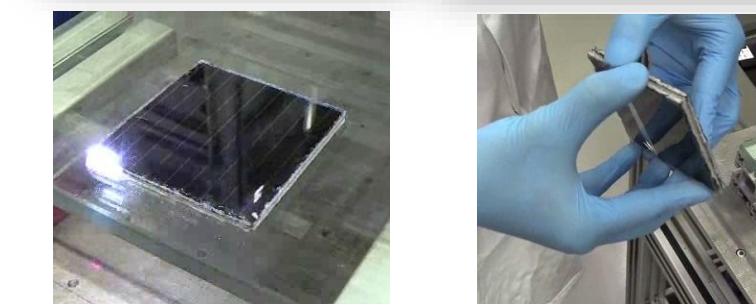
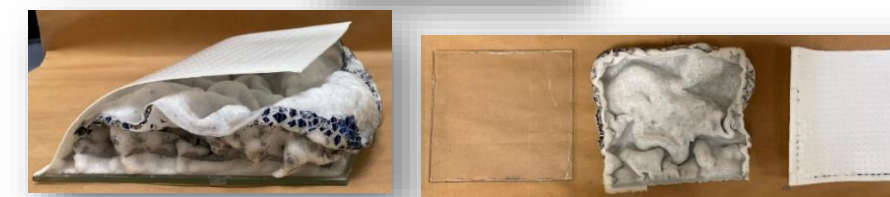
Mechanical delamination by EVA foaming

- Intact glass sheet (recycling or re-use)
- Cells residues (for step 3)
- Polymer backsheet (energy fuel)

Optical process

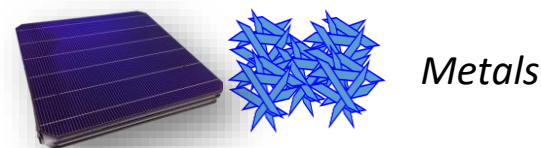
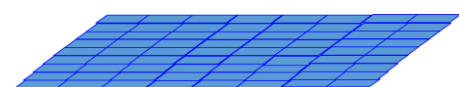
Optical delamination by EVA damaging

- Intact glass sheets (recycling or re-use)
- Cells printed on glass sheet (for step 3)



Step 3

MATERIALS RECOVERY



IL leaching & electrolysis

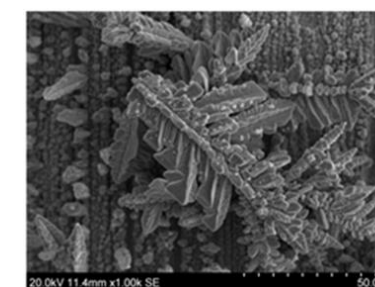
Metals recovery

- Ag (>99%), Si (MG)

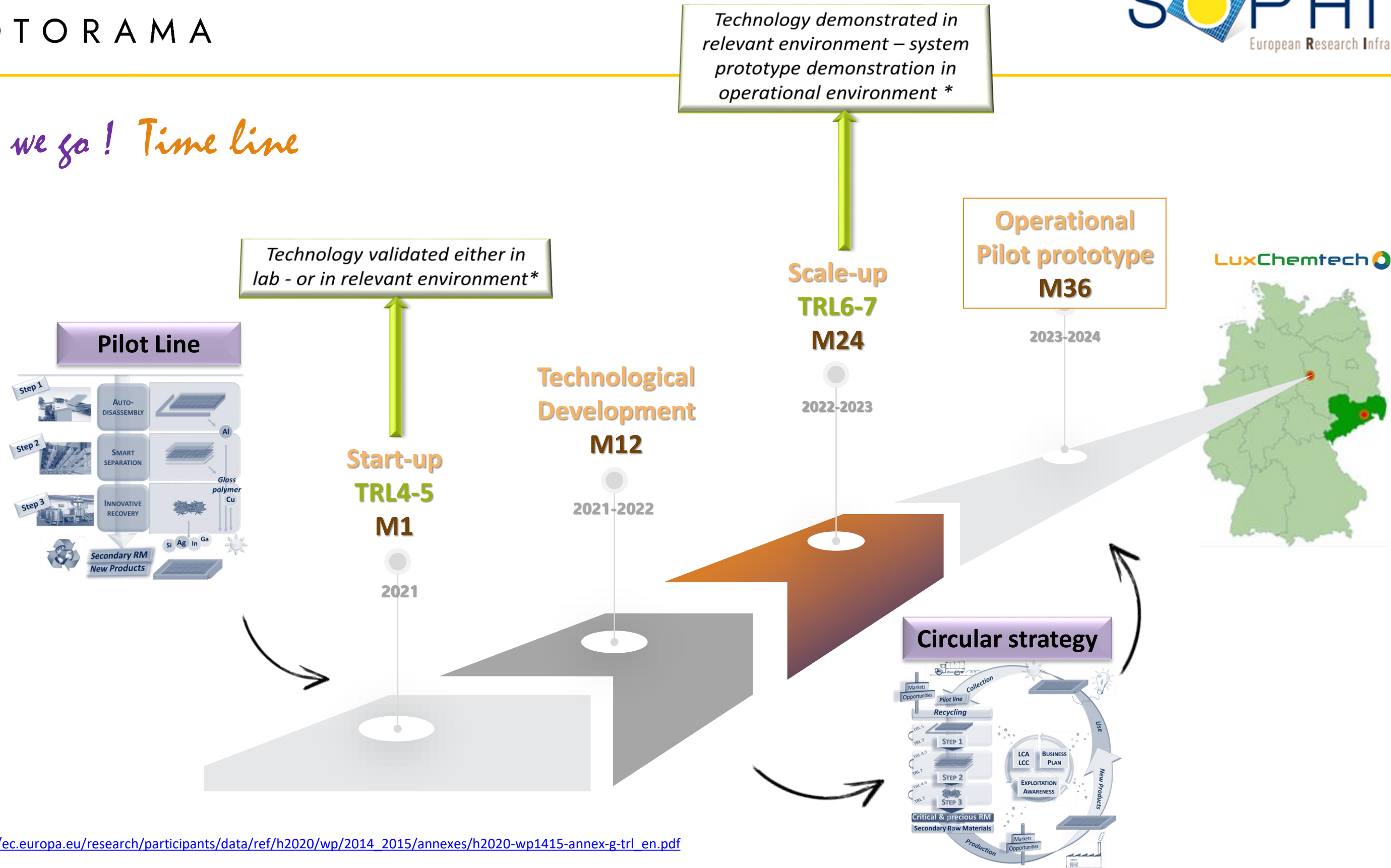
OSA & electrolysis

Metals recovery

- In (99%), Ga (99%)



Where we go! Time line



*https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf



Perspectives



Objectives

Go to Market

- Circular strategy
- New business opportunities



Test in manufacturing

- PV components
- Others value chains

Industrial validation

Technology scale-up

- Disassembly
- Delamination
- Metal recovery

*TRL 7 by the end
Pilot line demo
For 1200 tons a year*

Secondary Raw materials

- Characterization
- Recovery ratio

New products

- Glass (sheet, cullet)
- Metals (Ag, Si, In, Ga)

High-tech / high-value products

*Global recovery ratio > 98 %
Metal purity 98-99.999 %*



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Thanks for your attention !



Maltha



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