Supporting material to the toolkit: *Recycling of silicon-based PV modules*

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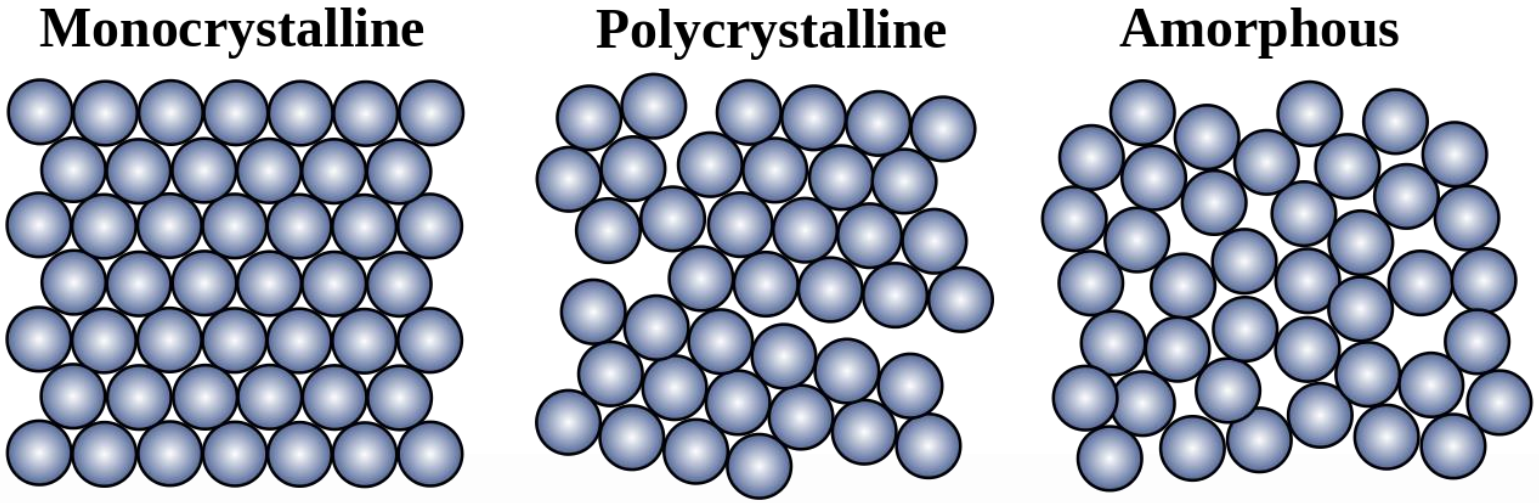
Photovoltaic panels:

- Efficiency about 18-20% (depending on the typology).
- Average lifetime up to 30 years.
- CO_2 emissions compensated in 1-2 years and investment in maximum 10 years.

Photovoltaic panels:



- It does not exist just one type of silicon solar cell!

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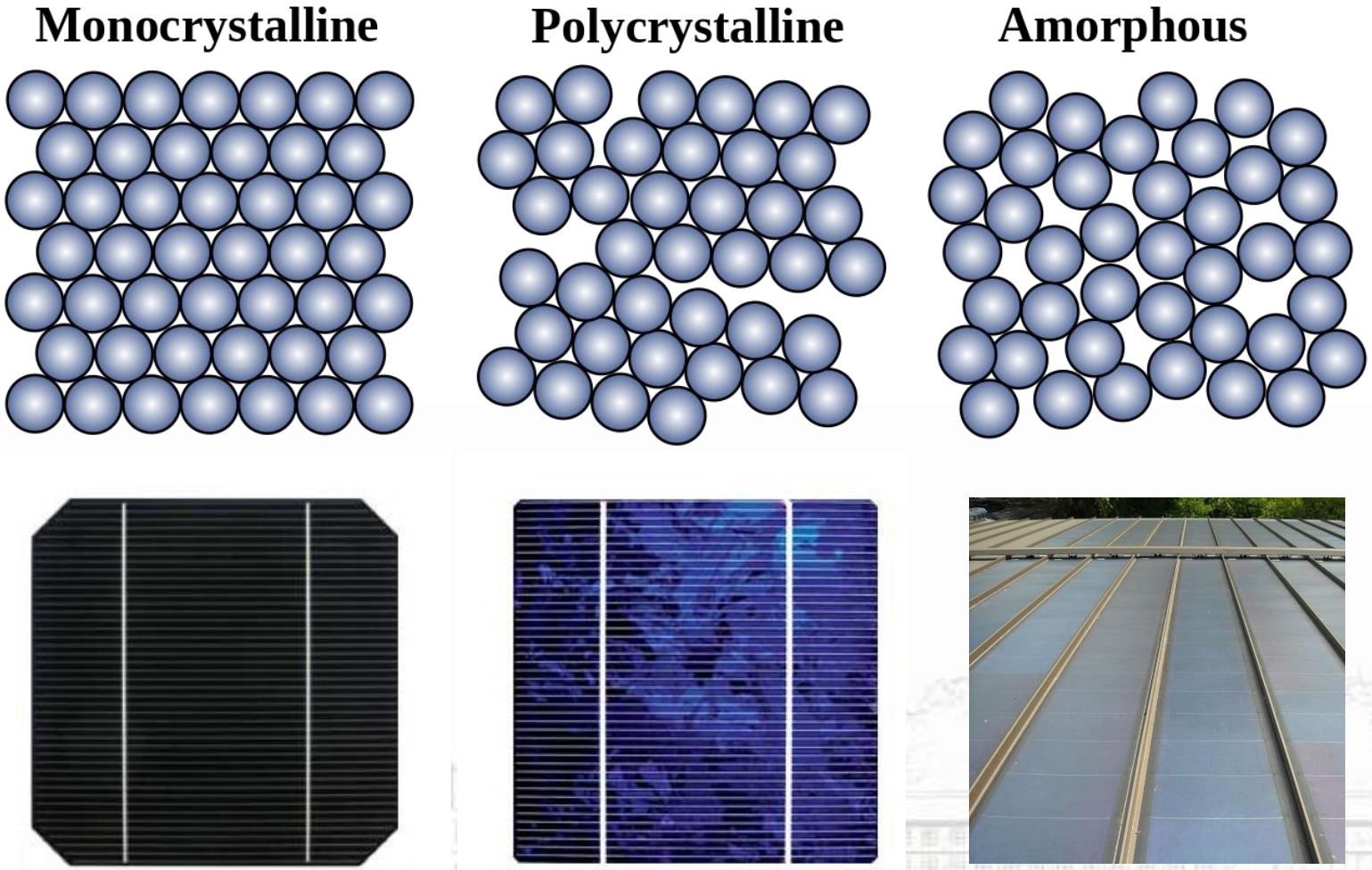

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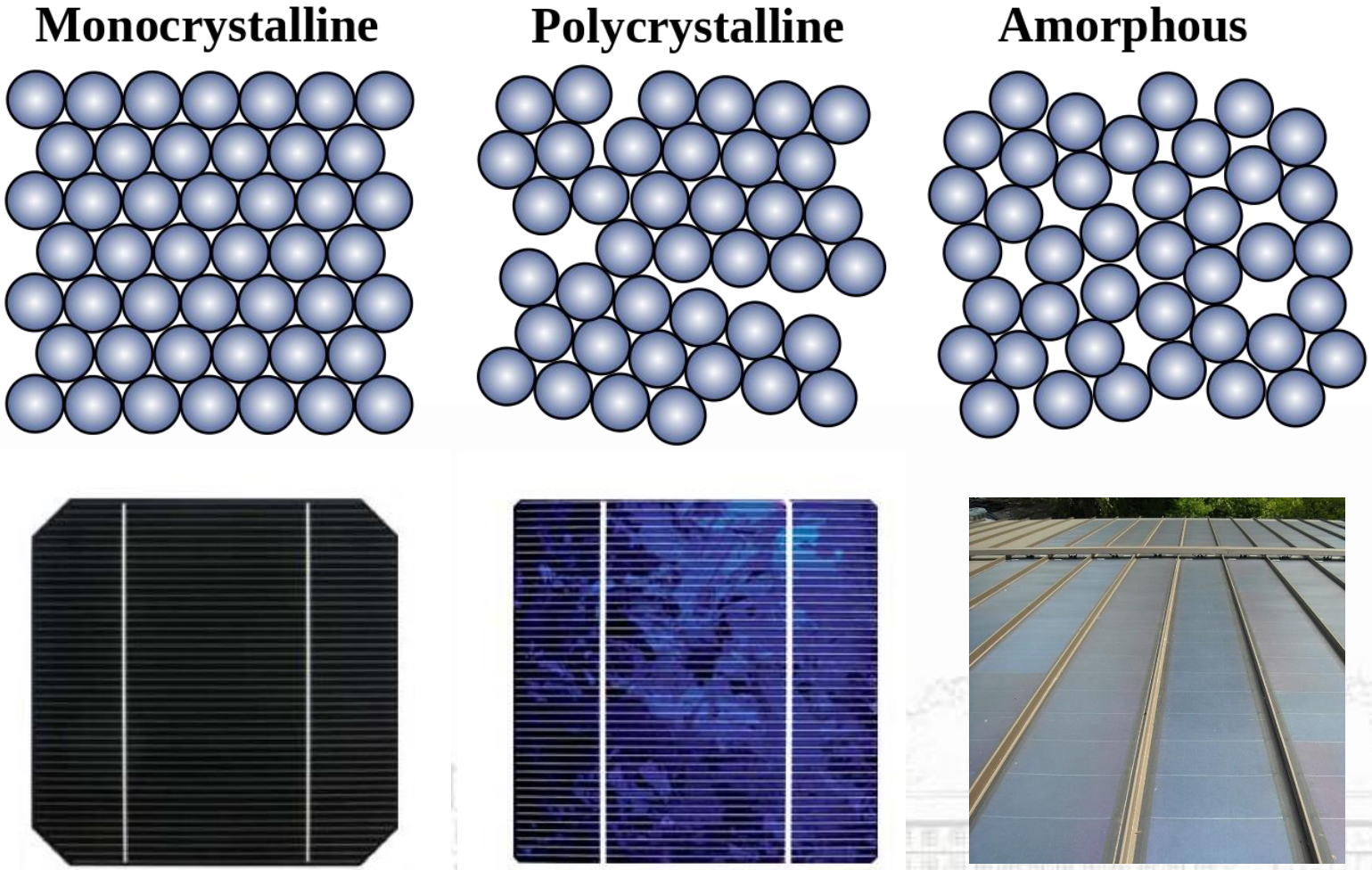

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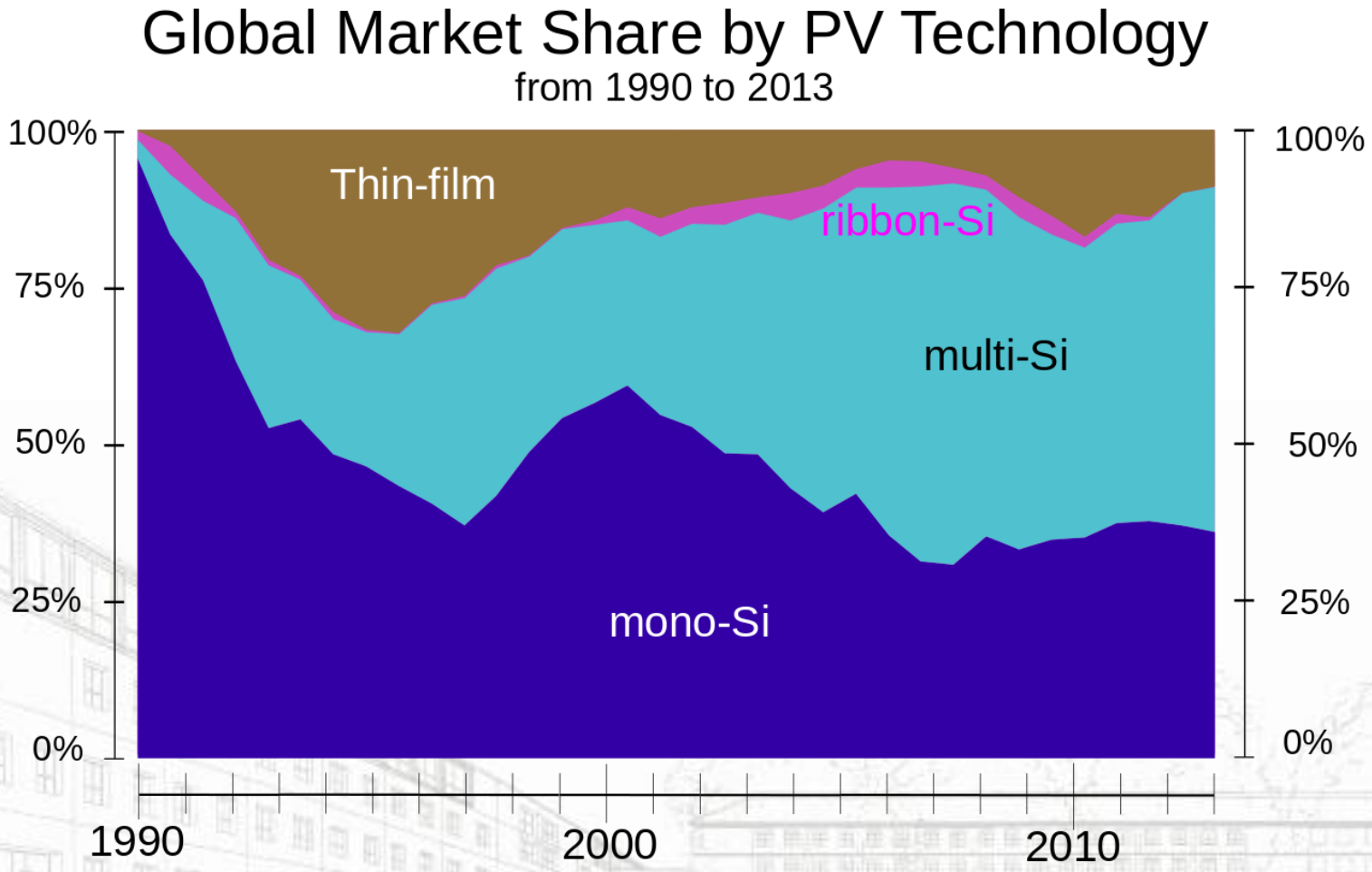

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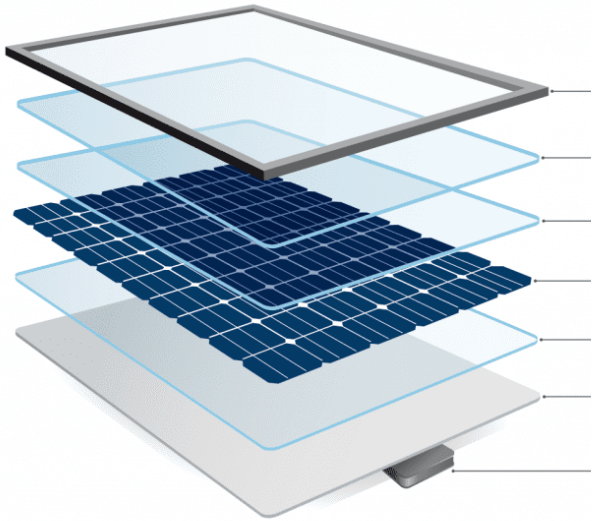

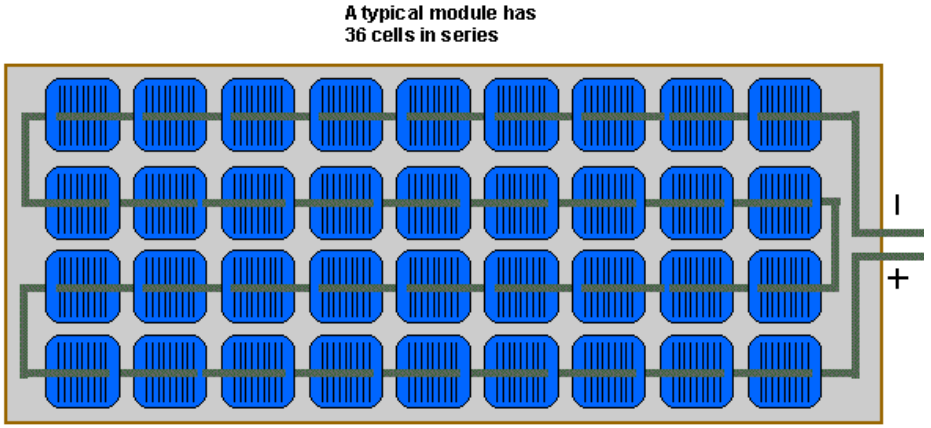

- But not only silicon:

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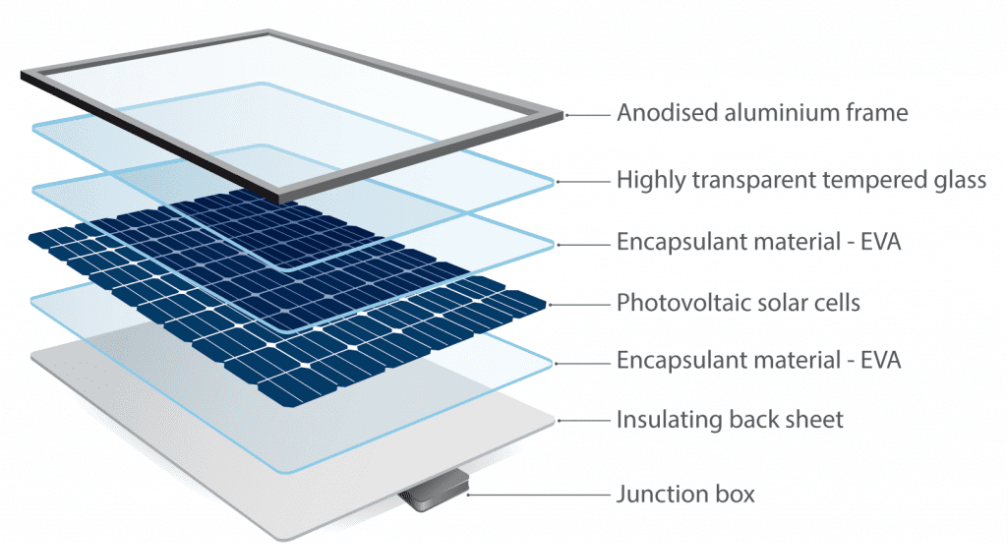

Panel component	Weight (kg)	Weight (%)	€ per kg	Value (€)	Value (%)
Glass	14.7	72.6%	0.05	0.74	5,8%
Aluminium	2.5	12.3%	1	2.5	20%
Silicon	0.61	3.0%	10	6.1	48%
Silver	0.0066	0.03%	500	3.3	26,2%
Other	2.44	12.2%	-	-	-
Total	20.3	100%		12.6	100%

- But not only silicon:
  - Silver
  - Aluminium
  - Copper, …

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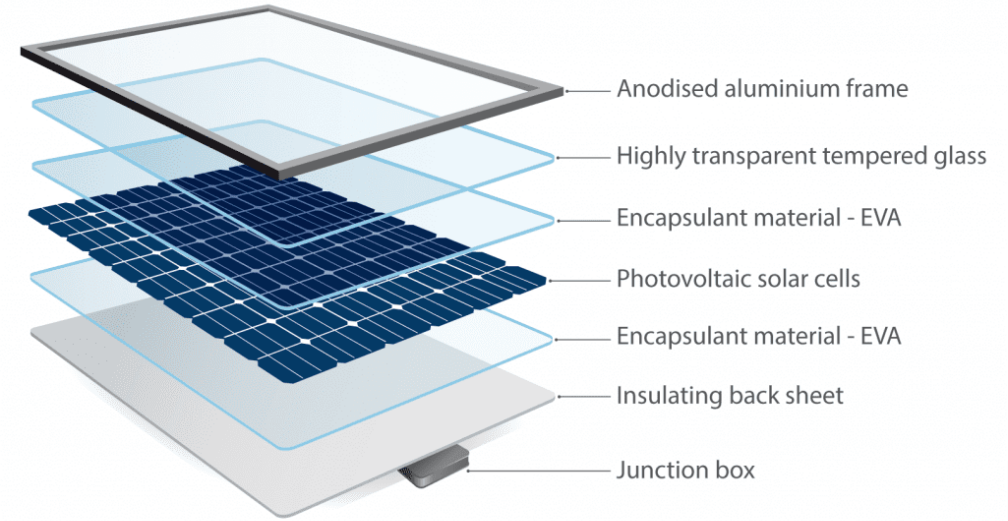

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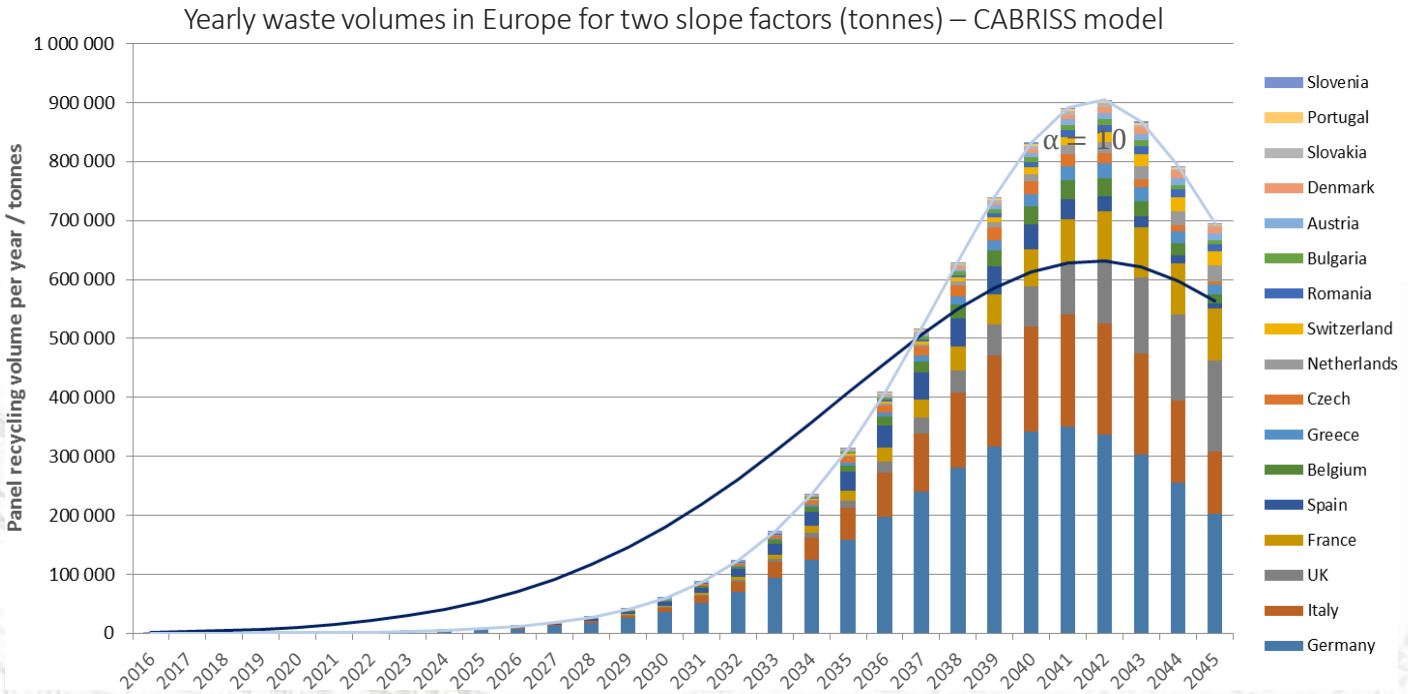
- But not only silicon: **CRITICAL ELEMENTS!**
  - Silver → **56% of global silver is used in photovoltaics!**
  - Aluminium
  - Copper, …

Future problems:

Increasing the installations, the number of solar panels reaching the end of life will grow as well *(peak expected in 2042).*



- PV panels are included in the new RAEE guideline.
- *The recycling of PV panels, already in action, is legally regulated just in Europe.*

Does it worth?

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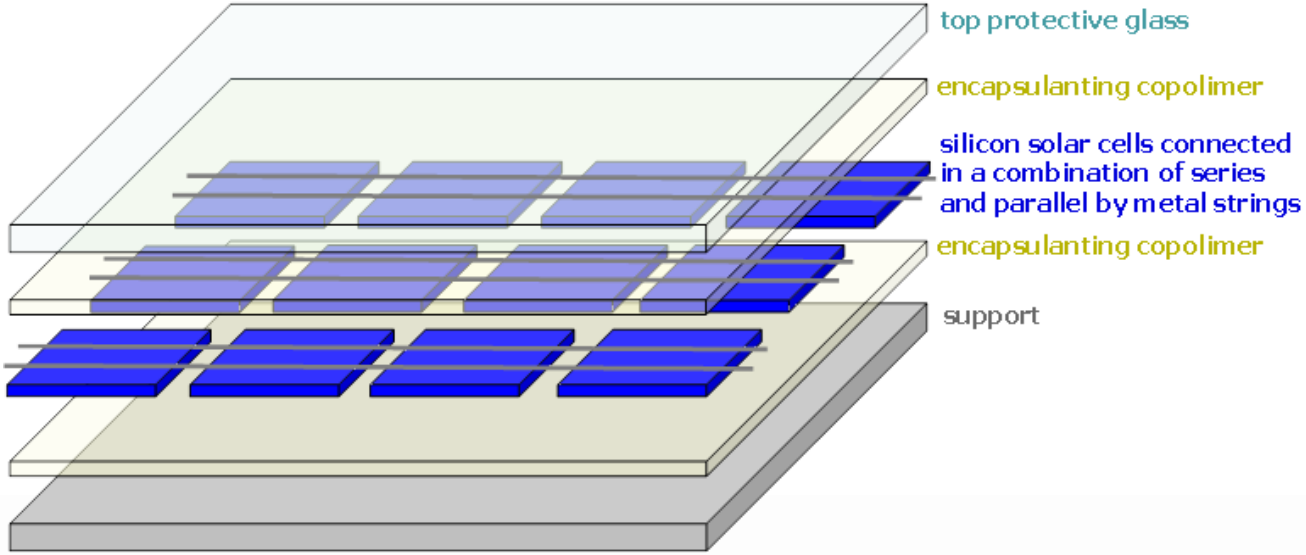
ECONOMICALLY YES!

- ✓ By 2036 **1.210.000 tons of PV wastes** will be collected in Europe!
- ✓ In 2045 the cumulative value of the recycled Si in the market will be of the order of **2.5 billion of euros** (<10 $/kg), plus **500 million of euros** each year coming from the recycling of other elements (i.e.: Ag, In).

ENVIRONMENTALLY YES!

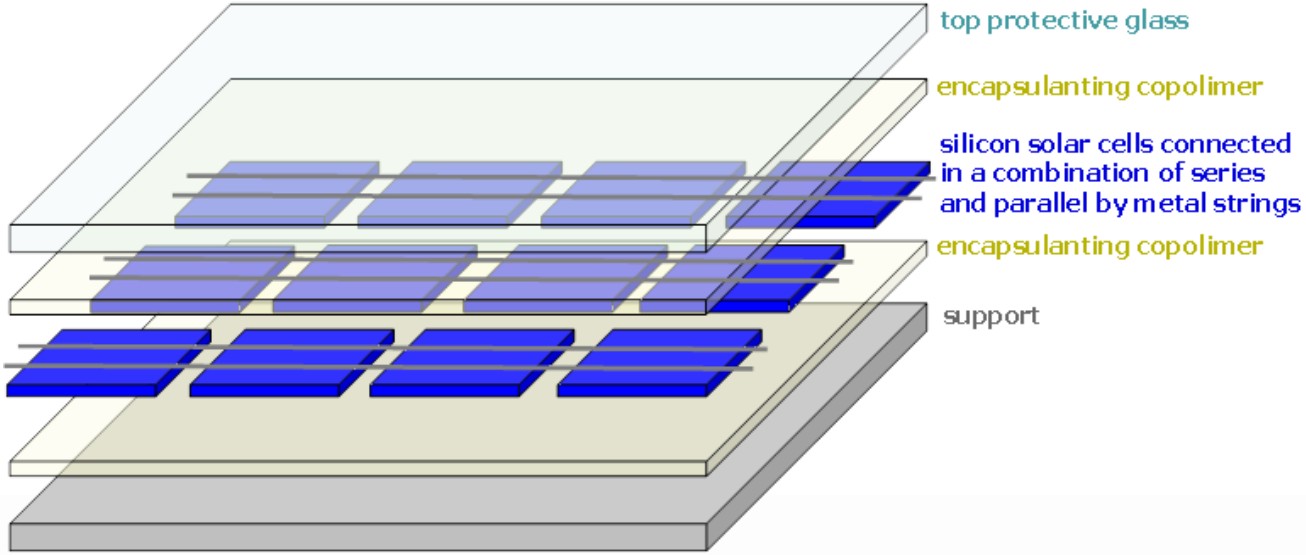
- ✓ The environmental impact of the panel production **is significant**
- ✓ Ag and In mines are in **rapid depletion.**

Recycling technologies



- Aluminium, glass and silicon are nowadays recycled through thermal, mechanical and chemical methods.
- The recycling processes of photovoltaic modules are:
  - Disassembling to remove PV frames
  - Removing the encapsulant of the laminated structure (this is the most difficult process)
  - Recovering of metals from the silicon cell.

Recycling technologies



In order to remove the encapsulant from the laminated structure, it is possibile to use:

- Mechanical approach (cutting, crushing and grinding): (Note: a mechanical process uses less energy than a thermal process that reaches temperatures up to 450 °C).

Recycling technologies

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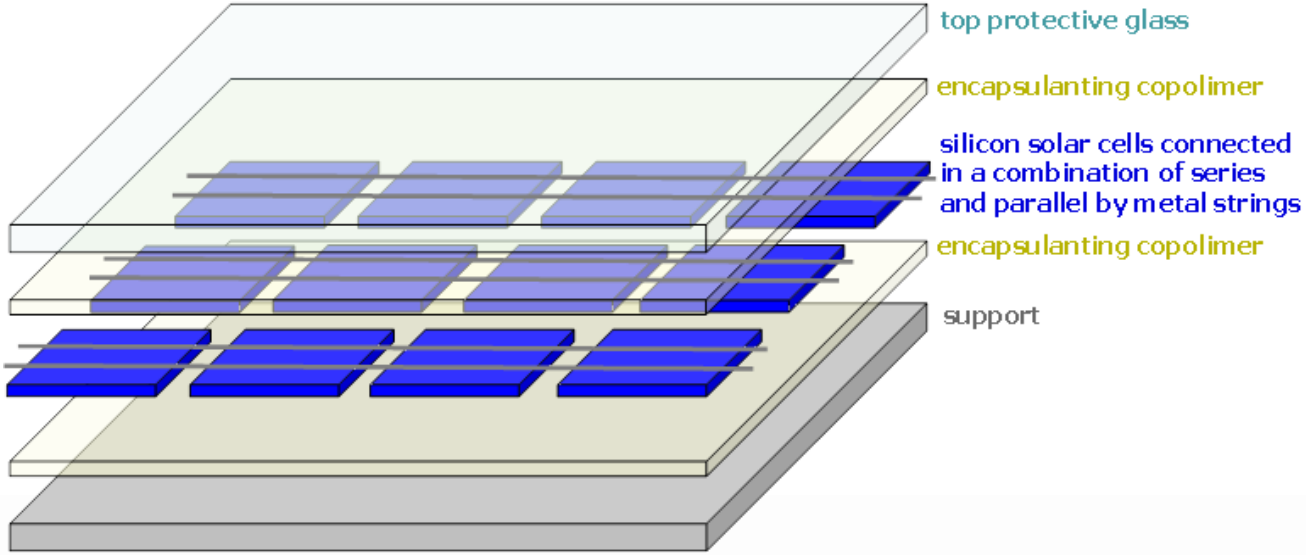
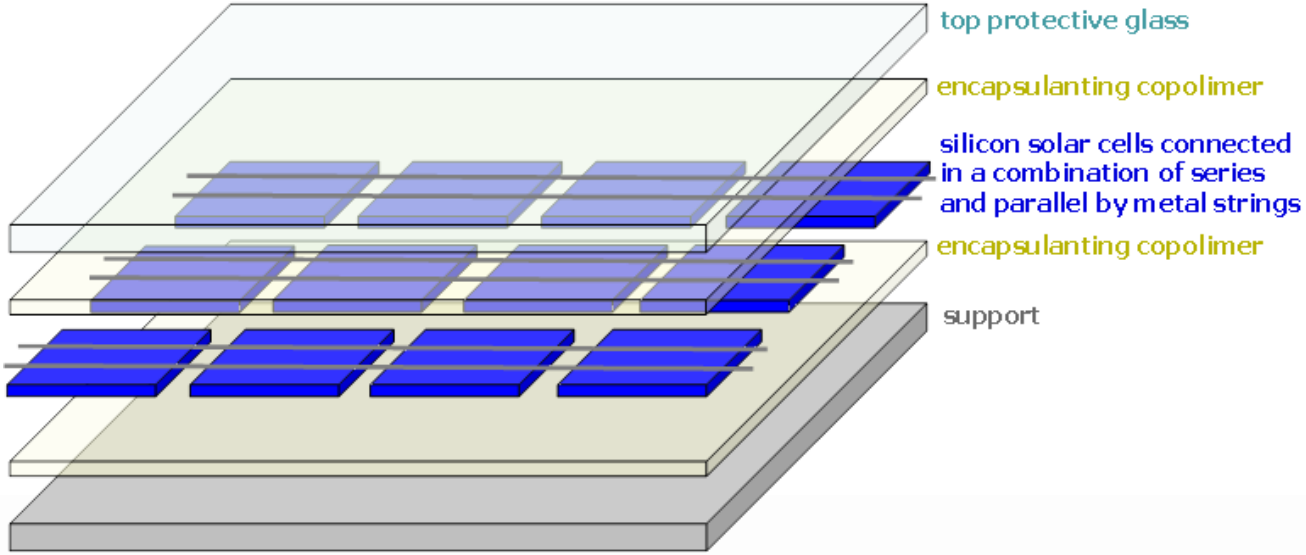


In order to remove the encapsulant from the laminated structure, it is possible to use:

- THERMAL APPROACH (combustion process): the recovered materials are glass, Si cells and electrodes. The advantage of the thermal approach is that glasses and silicon cells can be recovered without any breakage.

Recycling technologies



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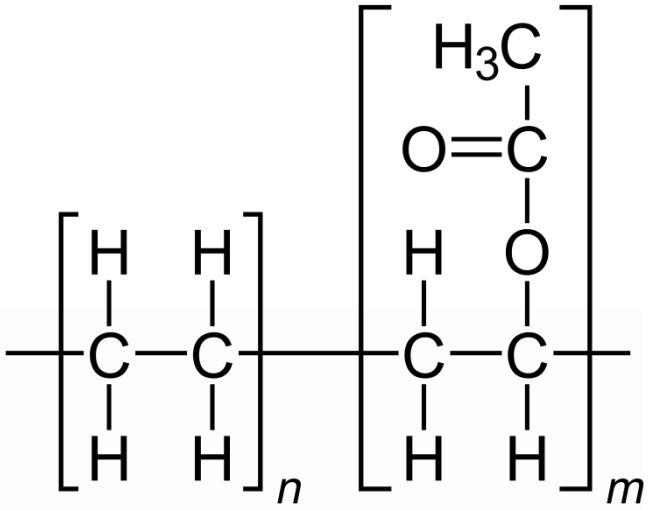
Experiment:

LIST OF MATERIALS:

- 2 glass slices 5cm x 5cm.
- 2 EVA sheets 3cm x 3cm.
- 1 PV Si cells 2.5cm x 2 cm.
- 2 heat resistant gloves for temperatures up to 250°C
- Thermal plate (or flatiron)
- High temperature resistant support



Ethylene vinyl acetate (EVA)

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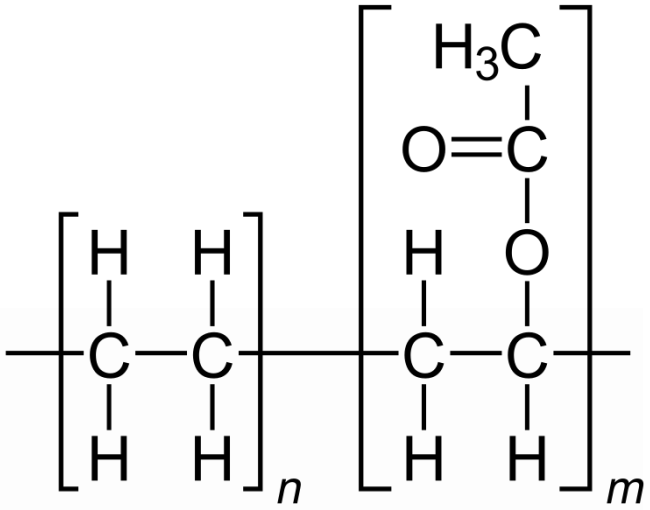
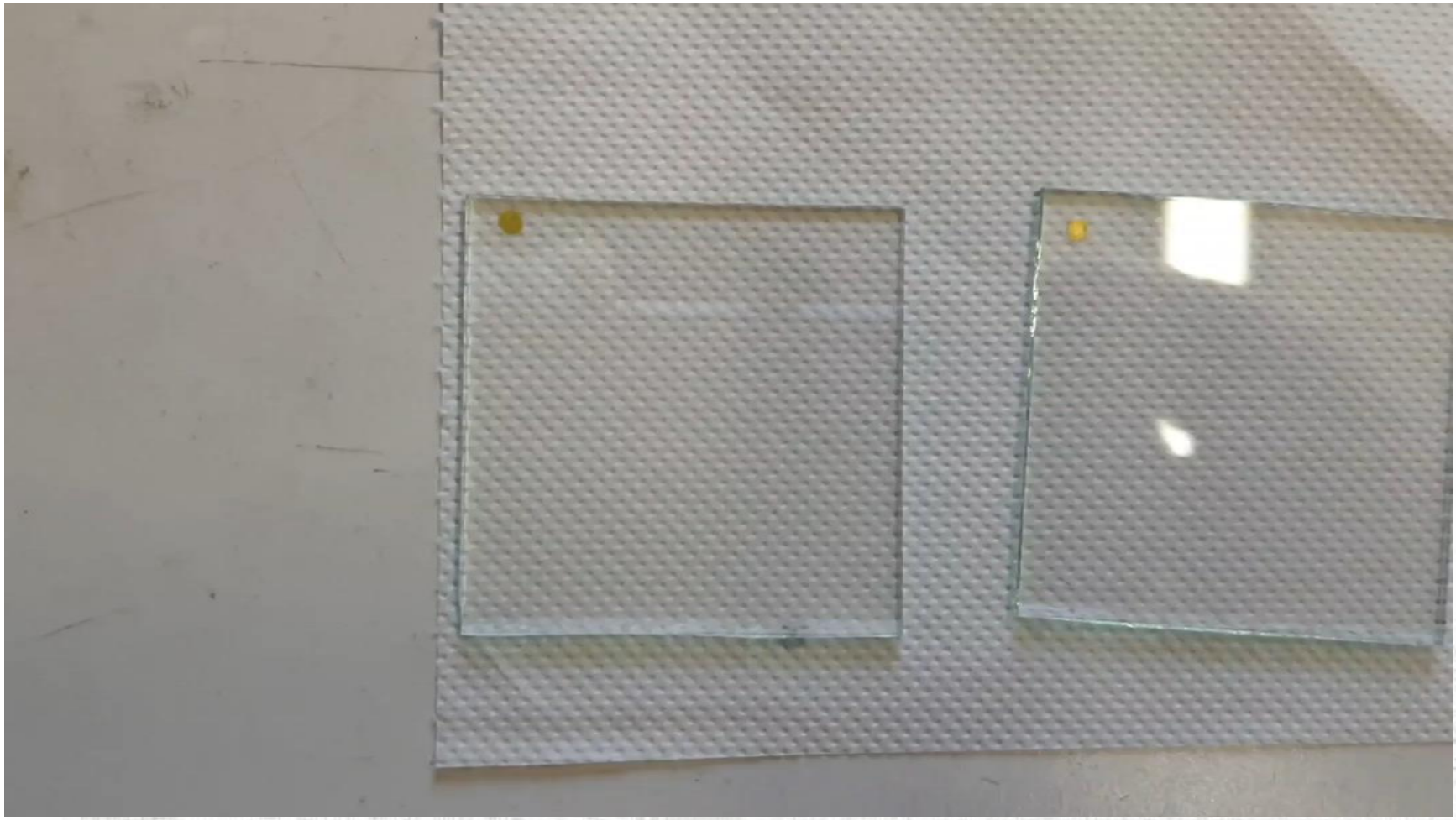


Ethylene vinyl acetate (EVA)

POLYMER

Experiment:



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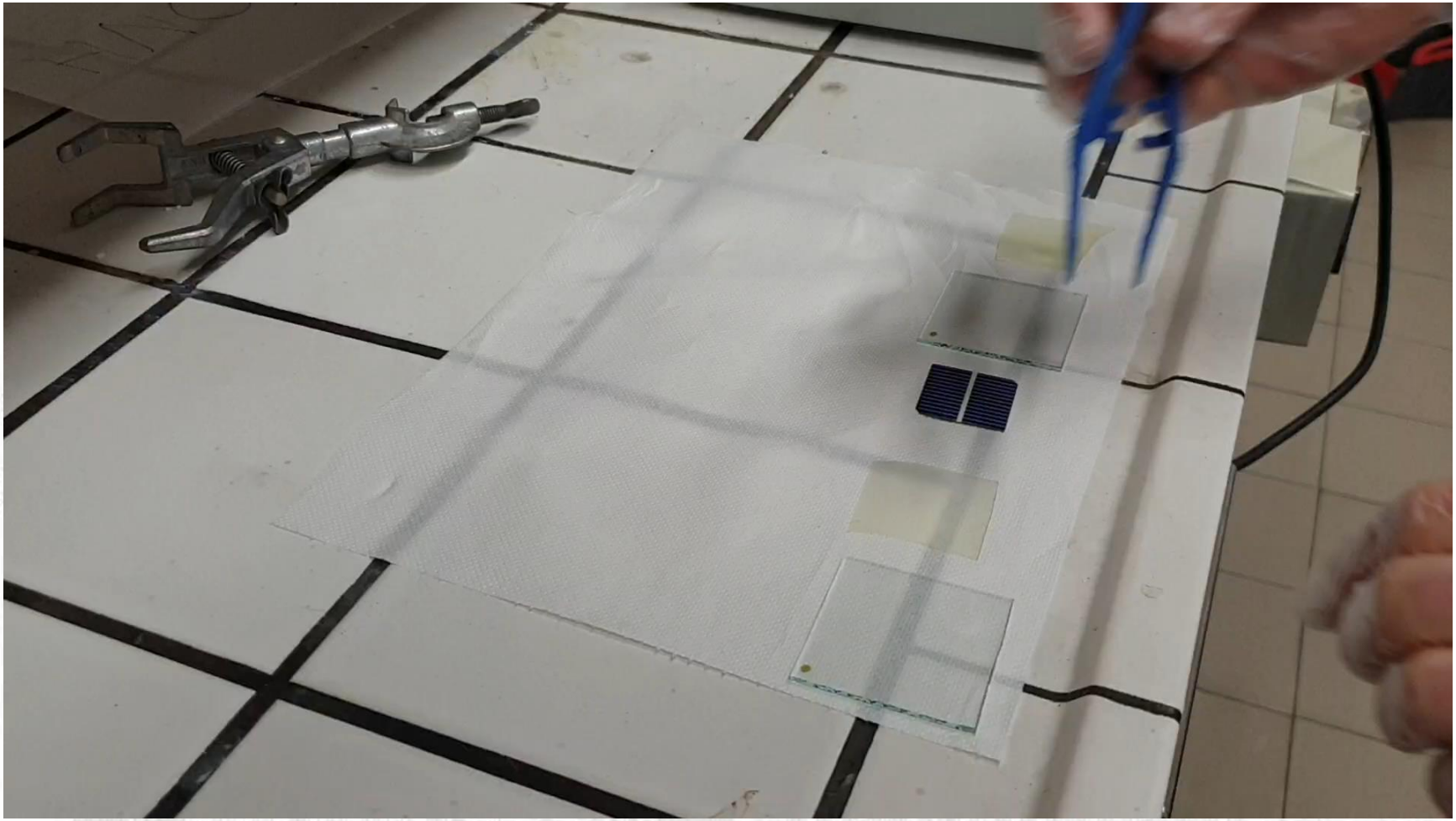
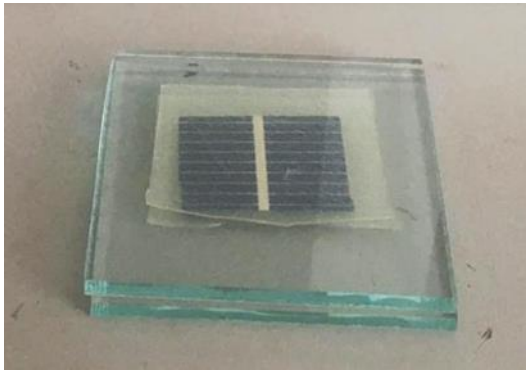
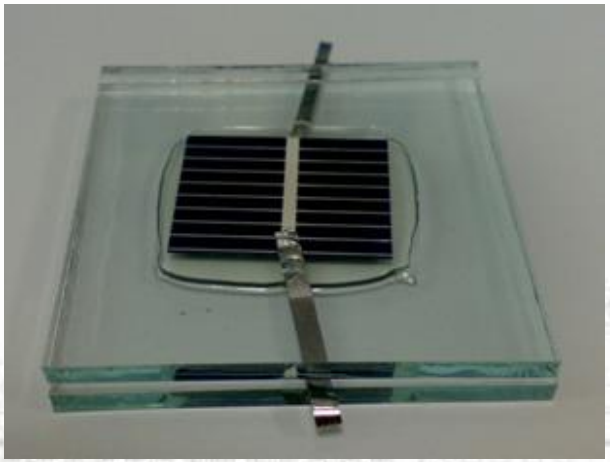


Experiment:

SILICON CELL ASSEMBLING:



The cell needs to be sealed in order to avoid the water infiltration or the movement of the composing elements.



To do so, the device is heated up to 150°C: at that temperature, the EVA sheets soften and polymerize, physically connecting all the elements.

Experiment:

Experiment:

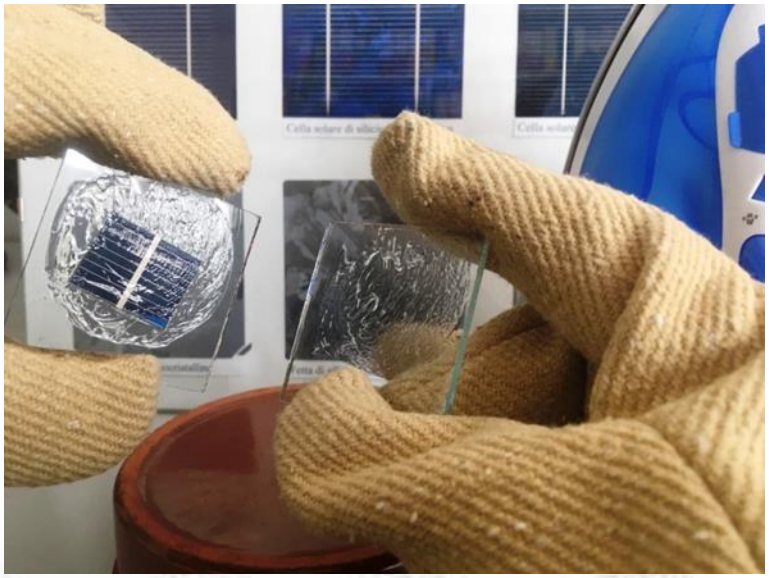
Experiment:

Experiment:

CELL DISASSEMBLING:

Heating up to high temperature (250°C in lab, 450°C in the industry) the EVA polymer further softens and enables the separation of the several components

Therefore, it leads to recover intact materials and address them to a new use!



Experiment: