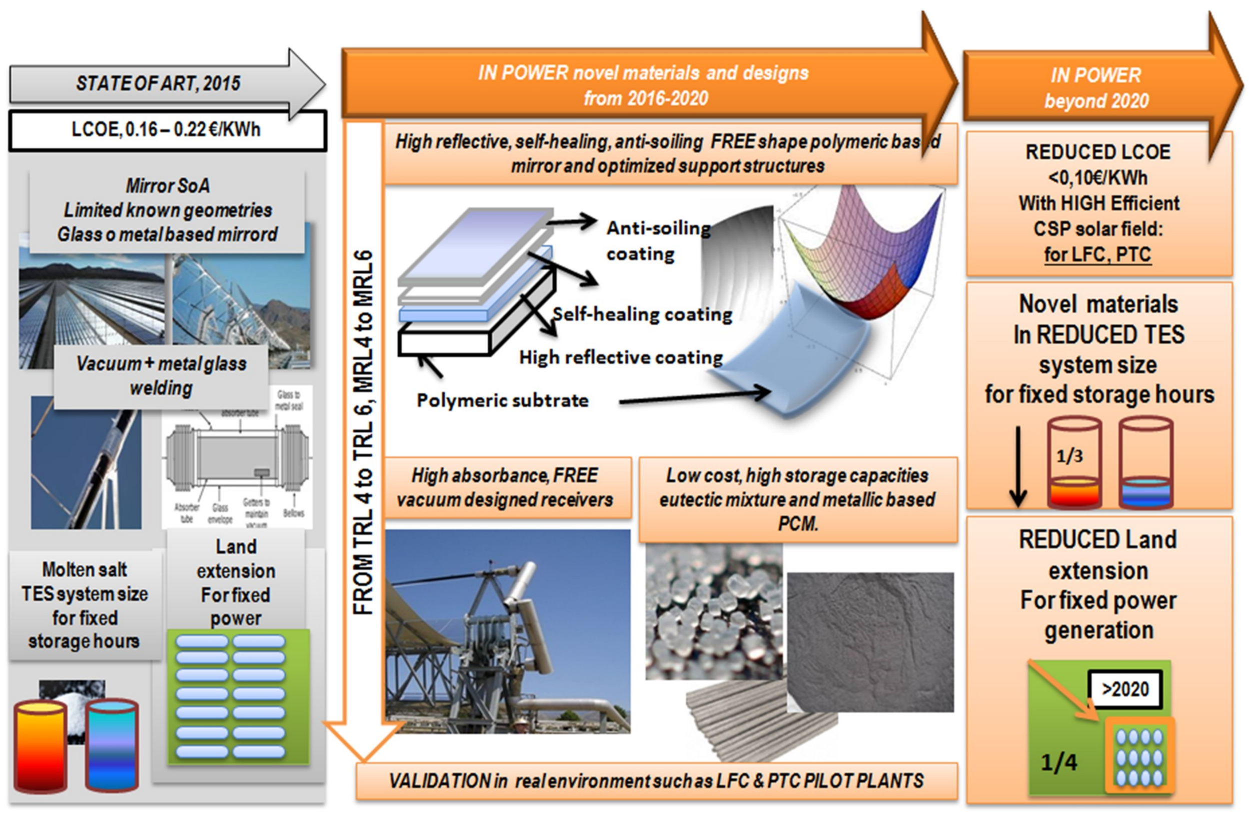
Environmental life cycle assessment of innovative advanced material solutions in Concentrated Solar Thermal technology as a tool for decision making and to drive sustainability

Claret, Ariadna[1] (aclaret@leitat.org); Escamilla, Marta[1]
[1] LEITAT TECHNOLOGICAL CENTER, Terrassa (Spain)

INTRODUCTION AND OBJECTIVES

The aim of IN-POWER project is **to develop and integrate innovative material solutions and manufacturing processes into concentrated solar technology to increase the efficiency while simultaneously reducing the environmental impact associated and decreasing the energy production cost**. The **environmental assessment** have been performed during the execution of the project as a **decision maker** looking for high performance **materials and component** but **environmentally friendly**.
To achieve this objective **a set of advanced solutions have been developed**:

- **A light polymeric mirror** with high reflectance, self-healing, anti-soiling and glass-free.
- An **optimized and lighter mirror support structure** using composites.
- New robust **absorber coatings for non-vacuum operations** and new high spectrally selective coatings **for vacuum operations** to work at high and low-mid temperatures, to convert light into heat.
- High-operating-temperature **thermal storage materials for TES** to store energy as heat and to dispatch electricity during 24h.



MATERIAL AND METHODS

The **Life Cycle Assessment (LCA) methodology** has been used to conduct the environmental assessment of the IN-POWER solution.
It have been considered in the analysis the **construction stage** of all the materials and components (manufacturing), the **operation and maintenance** of the validated prototypes, and the **end-of-life** of the mirrors. **Inventory data** from partners has been prioritized; when primary data was not available, standard processes from literature and commercial databases (Ecoinvent 3.5 and GaBi 8006) have been used. Different **functional units** have been established when hot-spot analysis of each component have been performed. Alternative materials and configurations have been considered and its environmental performance have been evaluated, as a decision-making tool. For the environmental assessment of the IN-POWER Pilot Plant (80 MWh/year), the functional unit fixed was thermal KWh produced/year. When data was available (mirror substrate, anti-soiling coating, mirror support structure, non-vacuum absorber and thermocline TES system) the environmental profile of the IN-POWER solutions have been **compared with reference materials/components**.

RESULTS AND CONCLUSIONS

The results reveals that in general, **IN-POWER solution brings important environmental benefits** compared with reference CSP components (see figure 2). Highlights the **polymeric mirror**, that has been demonstrated to has lower environmental impacts than metallic foils and glass mirrors for most of the impact categories studied, thanks to its lightness, reuse potential (V4) and lower cleaning requirements because of the new anti-soiling formulated and applied. Concerning the **mirror support**, the use of a support made by glass fibre reinforced polymer, causes also lower environmental impacts than a standard aluminium structure, and brings additional environmental impact savings thanks to its lightness (e.g.: during transport operations -less CO_2 emissions-). To stand up, also, the **TES materials and systems**, and specifically, the thermocline TES system configurations designed, that bring important environmental trade-offs in comparison with reference systems.

Polymeric mirror		Absorber coatings		Solar Salts		Thermocline TES system		Multi-stage TES system	
Developments	Range	Developments	Range	Developments	Range	Developments	Range	Developments	Range
V1 (complete)		Non-vacuum operations		Ternary mixture		1P#1		2P#1	
V2 (intermediate)		Vacuum operations at high temperature		Quaternary mixture		1P#2		2P#2	
V3 (intermediate)		Vacuum operations at high temperatures with Mo				1P#3		2P#3	
V4 (reusable)		Vacuum operations at low -mid temperature				1P#4 (5 and 10%)		2P#4	

Figure 1. Summary of the alternative IN-POWER solutions developed and analysed and its environmental performance (legend: dark green = best environmental performance; red = worst environmental performance).

IN-POWER component		Reference component	Environmental trade-offs
Polymeric mirror	Reusable version (V4)	Glass	⇩ 32%
		Metallic foils	⇩ 50% ⇩ 78% ⇩ 100%
	Complete but non– reusable version (V1)	Metallic foils	⇩ 43% ⇩ 75% ⇩ 100%
Lighter mirror support structure (Glass fibre reinforced polymer)		Aluminium mirror support structure	⇩ 81% ⇩ 44% ⇩ 74%
Thermocline TES system		2 Tank Indirect	⇩ 65-88% ⇩ 64-91% ⇩ 50-100% ⇩ 64-85%

Figure 2. Environmental trade-offs (benefits) of IN-POWER solutions, in comparison with the reference components.

FINAL RECOMMENDATIONS

To improve the environmental profile of IN-POWER solution and to drive sustainability in CSP architectures, concerning the alternative solutions, according to Figure 1, the most recommended are those on dark green. To avoid those marked in red. Other recommendations as a result of the assessment are: 1) the optimization of manufacturing processes in terms of energy consumption; 2) reduce when possible the use of metals (chromium, molybdenum, tungsten, aluminium); 3) reduce as much as possible the structural materials (e.g.: tanks) and involved materials (steel, stainless steel, concrete).

The IN-POWER consortium consists of 10 partners from 6 different European Countries: LEITAT, Acondicionamiento Tarrasense (Spain), VOTTELER (Germany), MAGTEL (Spain), KOLZER (Italy), NEMATIA (Spain), GEOCAD (Spain), IK4-TEKNIKER (Spain), CEA – LITEN (France), FERTIBERIA (Spain), Italian National Agency for New Technologies, Energy and Sustainable Economic Development (Italy). *This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 720749 .*

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