next-CSP

High Temperature concentrated solar thermal power plant with particle receiver and direct thermal storage

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Deliverable D8.1

WP8 – WP Environmental assessment of the technology

Deliverable D8.1 Report on LCA of Next-CSP system

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Nomenclature			
ATS	Advanced Thermal System	LCOE	Levelised Cost of Energy
CSP	Concentrated Solar Power	LMs	liquid metals
DCB	Dichlorobenzene	NRE	Non-renewable energy
DNI	Direct Normal Irradiance	NREs	Non-Reviewable Energies
EPBT	Energy Payback Time	PV	Photovoltaic
EP	Eutrophication potential	SEC	Solar Energy Conversion
GHGs	Green House Gases	SPT	Solar Power Tower
GWP	Global Warming Potential	STPP	Solar Thermal Power Plant
HTFs	heat transfer fluids	STWT	Solar Thermal Wind Tower
ISEGS	Ivanpah Solar Electric Generating System	SEDC	Solar Energy Development Centre
LBE	Pb-Bi eutectic	USSE	Utility-Scale Solar Energy
LCA	Life Cycle Assessment	WoS	Web of Science

1 Introduction

1.1 WP8 - Environmental assessment of the technology.

WP8 addresses the environmental life-cycle assessment of solar power production using the Next-CSP technology and discuss its comparison to current solar thermal technologies. **Task 8.1** estimates life cycle environmental impacts of the Next-CSP concept: 'cradle to grave', extraction and manufacture of raw materials, construction and operation over its lifetime and its decommissioning. A modular approach, i.e. subdividing the system into several sub-systems, is used. This deliverable covers the work carried out in Task 8.1.

Then, **Task 8.2** addresses the Next-CSP technology with respect to current CSP technologies, of which the results will be presented in Deliverable D8.2.

1.2 Introduction to LCA and standards

Life-cycle assessment (LCA) or life-cycle analysis, refers to a methodology that is adopted in order to assess the environmental impacts raised from various stages of a commercial product, process, or service life cycle [1]. A LCA of a typical SPT covers various stages from construction to recycling, including raw materials excavation, materials processing, construction of the parts, transportation and assembly of the constructed parts, operation of the constructed plant, decommissioning, recycling and disposal of the products [2,3]. Such environmental impacts can be directly influenced by some factors such as the facility scale, the type of technology applied, and dependence on the fossil fuels for auxiliary needs, etc. Moving towards sustainable development [4–6] of such technologies and promoting their commercialization require a better understanding on the environmental subsequence that can be expected from the establishment of such technologies and possible technical advances to minimize the environmental adverse impacts.

In this section, life-cycle analysis (LCA) and the background of the new European Standard EN 15804:2012 [7] are introduced, including Module D, which allows credits to be taken now for the eventual reuse or recycling of material in the future, at the end-of-life stage.

LCA is increasingly being used to assess the environmental potential impacts associated with the entire life of products. As already mentioned, it quantifies the resource use and environmental emissions associated with the evaluated product (Life-cycle Inventory, LCI) and the corresponding potential impacts (such as Global Warming Potential, Eutrophication Potential, Acidification Potential…). Those potential impacts are potential effects resulting from the release of gases in the atmosphere or substances in the rivers for instance. As an example, Global Warming Potential, expressed in terms of equivalent mass of CO_2 per considered unit (e.g., kg equivalent CO_2 per kg of EN 1.4003 stainless steel) is the standard measure of how much heat a considered gas is able to trap and so how much this gas is capable of increasing the earth temperature. To each gas *i* is associated a characterization factor GWP_i by which the mass is multiplied to obtain the contribution of this gas to greenhouse effects. A GWP_i is calculated over a specific amount of time (conventionally 20, 100 or 500 years).

The importance of LCA has long been recognized by the European Commission as the best framework for assessing the potential environmental impacts of products and it was mainly developed for designing low environmental impact products. The framework and generic methods of environmental LCA are standardised in the ISO series 14040-14044 [8,9] and for environmental analysis of products, it has achieved good international agreement. The interest of using LCA for entire construction works evaluations began to rise in the last decade and, today, several building LCA tools have been or are under development in different countries. Since 2010, the work of the Technical Committee TC350 [10] (which is responsible for the development of standardized methods for the assessment of the sustainability aspects of new and existing construction works and the standards for the environmental product declaration of construction products) has been implemented into a new suite of European standards, Figure 1. Quantitative indicators for the environmental, social and economic performance of buildings are provided. Among the aforementioned suite of standards intended to assess the sustainability of construction works, EN 15804:2012 [7] provides a structure to ensure that all Environmental Product Declarations (EPD) of construction products, such as carbon steel or stainless steel, are derived, verified and presented in a harmonised way.

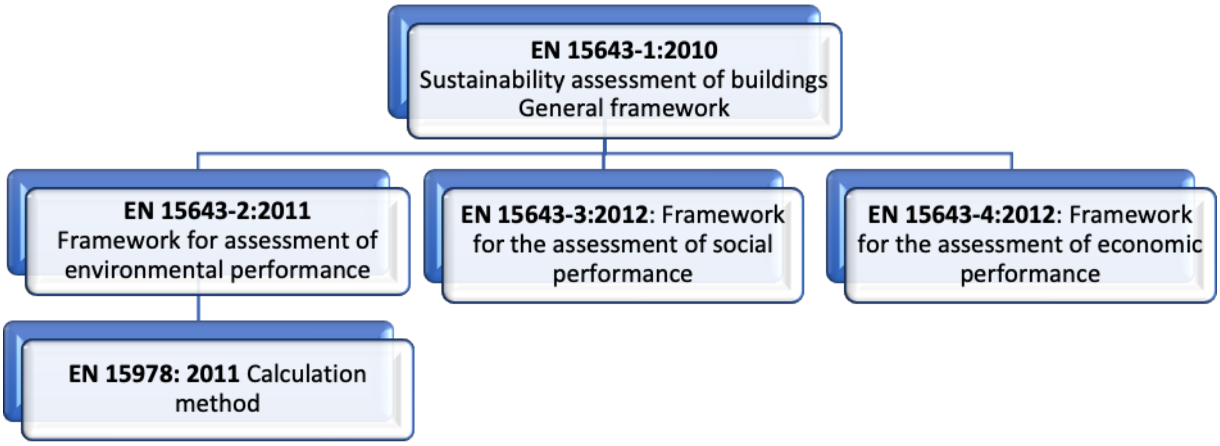

Figure 1. European standard suite for the assessment of the sustainability of building (credits to [7]**)**

Data provided in EPDs are based on LCA and the information may cover different life-cycle phases. Two prevailing EPDs exist plus a third one which may include an optional stage:

- "C*radle to gate*" i.e. the product stage only: raw material supply, transport, manufacturing and associated processes are included (modules A1 to A3 in EN 15804:2012);
- "C*radle to gate with options*" contains the product stage (modules A1-3) whereas installation into the building (modules A4-5), use, maintenance, repair, replacements and refurbishment (modules B1-7), demolition, waste processing and disposal (modules C1-4), reuse, recovery and/or recycling potentials, expressed as net impacts and benefits (Module D) are optional modules i.e. they may or not be included.

The module D therefore allows benefits to be taken now for the eventual reuse or recycling of materials in the future. The third one "*cradle to cradle*" includes all modules except module D, which remains optional. Today, recycling is becoming more widespread, but it often implies downgrading of the material, and reusing the material in this downgraded form, whereas selective dismantling and material recycling/reuse results in significant environmental and economic benefits. For indefinitely recyclable materials such as carbon steel and stainless steel, the inclusion of module D is of prime importance.

1.3 Next-CSP concept – System description

The main principle of the concept is illustrated in Figure 2. The system is composed of two sub-systems: the solar loop and the heat conversion loop. The former sub-system consists of a concentrating solar system (a heliostat field in our case), a high temperature solar receiver and a two-tank heat storage system. The latter sub-system consists of a heat exchanger and a gas turbine (power block) working in the hybrid mode. This architecture is similar to that of molten salt power towers where molten salt is replaced by fluidized particles and the steam turbine is replaced by a gas turbine. More precisely, a schematic representation of the proposed hybrid solar gas turbine is shown in Figure 3.

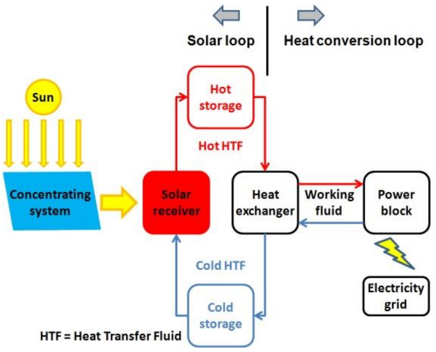

Figure 2. The general concept.

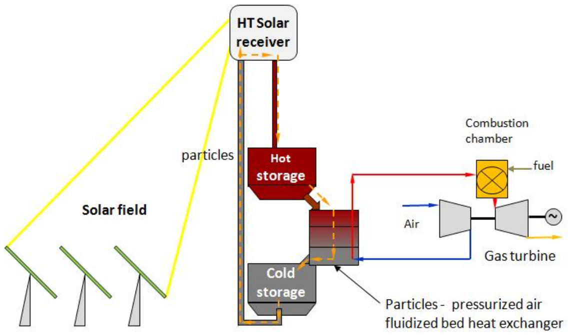

Figure 3. Proposed hybrid solar gas turbine concept with particle receiver

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