Definition of analysis levels

Annex 30

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TES for Energy Management and CO_2 Mitigation

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Keywords

- Thermal Energy Storage (TES)
- Process
- System
- Module
- Components
- TES material
    - Sensible
    - Latent
    - Chemical & Sorption
- Storage length
    - Short
    - Mid
    - Long
- Temperature level
    - Low
    - Mid
    - High
- Parameters
- Performance indicators
- Key performance indicators (KPI)
- Stakeholders
- Technology readiness level (TRL)
- Heat source
- Heat sink

1. Introduction

Thermal Energy Storage (**TES**) is a set of technologies that absorb and store the heat and cold produced in **processes** to later release it for being used in the same or other **process**. Therefore, **TES** never form standalone **systems**. Their utility is only meaningful when coupled to one or more **processes**. Furthermore, many different **processes** could take advantage of **TES**, resulting in a huge diversity of technologies that fulfil the above mentioned requirements.

There are three main families of **TES** technologies: **sensible**, **latent**, and **chemical** or **sorption** (commonly referred as **thermo-chemical**). Each of them fulfils the different TES requirement by using different **TES materials.** Additionally, **TES** systems are defined by two main parameters: **temperature level** (low, medium and high) and **storage length** (short, mid and long).

The availability of different **TES** technologies results in **systems** of varied complexity. Moreover, a lot of **TES** technologies are far from mature, except some specific cases in **sensible** and **latent**, and most of them are not commercial. Furthermore, there is not an established knowledge of all the **processes** that could benefit from **TES**.

Additionally, despite their potential, **TES** is generally neither considered in the design of processes nor promoted by policies. The development and implementation of **TES** technologies requires the fact of being able to measure and compare the performance of **systems** to be able to select the most adequate **TES** technology for each **process**.

Finally, the development of the **TES** technologies involves different **stakeholders** who are interested in different **parameters**, whose relevance might depend on the maturity of the technology and the type of analysis. These features rely on **parameters** that are specific to the technology. However, some of these **parameters** are useful for the comparison between technologies and **systems**, and are considered as **performance indicators**. Some of them are particularly relevant for the achievement of the goals and interests of the main **stakeholders**, and therefore are considered as **key performance indicators** (**KPI**).

As a result of the interaction between the different **stakeholders**, technologies, and technology readiness levels (**TRL**), research on **TES** is divided in different layers of detail (**levels**), which focus on different **parameters** and goals. Each level has its own relevant **KPI** according to the required research.

The complexity of analysis of **TES** requires clear definition of all the concepts defining the **levels** and identifying the relevant **KPI**. There are five main levels of research:

- Process
- System
- Module
- Component
- Storage material

Annex 30 is focused in studying the relevant **KPI** of **TES** at **system** level. However, this approach requires taking into account the interaction of the **system** with the **process** and the influence of the **modules**, **components**, and **TES material**.

2. Levels definitions

2.1. Process level

- Definition:

Annex 30 considers as a process any series of actions that require heat **sources** and heat **sinks** to achieve a result.

Application of **TES systems** to these **processes** is useful for increasing the utility or reducing the energy consumption and the greenhouse gas emissions.

- Boundaries:

Regarding Annex 30, the boundaries between the **process** and the **TES systems** are the point of contact between the fluid streams and the **heat source** and **heat sink**.

2.2. System level

- Definition:

A **system** is a set of connected **components** that operate together. A **system** is defined by its purpose and the method it uses for fulfilling it.

In the context of Annex 30 **system** refers to all the **materials**, **components** and **modules**, used exclusively by the **TES** device in order to perform its purpose of collecting, storing, and delivering heat.

The approach of Annex 30 considers that the **TES system** is attached to a **process**, but it is independent of it.

- Boundaries:

The **system** boundary is the point of contact between the fluid streams and the **heat source** and **heat sink**.

The **system** contains all the **components** and **modules** exclusively used by it.

2.3. Module

- Definition:

A **module** is a **component** or a **set of components** fulfilling a distinct and specific task inside the **TES** operation.

According to the Annex 30 approach, the **module** level helps in structuring the analysis of a **system**. Grouping **components** in a **module** might be required in the calculation of **system** KPI. However, no **KPI** are defined for this level, as the **modules** are very specific for each **TES system**.

- Boundaries:

A **module** involves one or more **components**.

A **module** can contain the **storage material**.

A **module** has a distinct task that is essential in the operation of the overall **TES system**.

A **module** task might not be related to storage capacity of the system (i.e. pressurization **module** in molten salts TES).

2.4. Component

- Definition:

Components are the smallest parts of the **TES**, which in combination form the overall **system**.

- Boundaries:

Components are single simple parts whose purpose is meaningless without the interaction with other **components**.

According to the approach of Annex 30, the **TES material** is not a **component**, but it might be contained and integrated into one or more **components**.

Components include all the fluid essential to **system** operation but not specifically used for thermal storage (i.e. heat transfer fluid).

Insulation is considered a **component**.

The **components** are elements and parts exclusively used by the TES **system**.

2.5. TES material

- Definition:

The **TES material** level involves exclusively the substances, mixture of substances, or reaction pairs that are the base of the thermal storage capacity of the system.

The characteristics of the storage material define the **technology** family, the **temperature level** and the **storage length** of the studied **system**.

- Boundaries:

The **TES material** level only includes the substances, mixtures of substances, or reaction pairs whose sole purpose is the thermal energy storage.

The **TES material** excludes any other substance that could be key to the performance of the **system**, which might involve coatings, insulation, heat transfer fluids, structural materials, lubricants, etc.

3. Case study: molten salt TES for CSP

A molten salt **TES** for CSP is presented as an example of the use of analysis levels. The whole **process** is the concentrating solar power plant (CSP), whose objective is to produce electricity using the sun as energy source. Therefore, it only has one **heat source**, the solar field, and one **heat sink**, the power block.

The **TES system**, the molten salt system, is connected in parallel to the **heat source** and **heat sink**. This means that the **process** can operate by providing heat directly from the **heat source** to the **heat sink** to produce electricity. In this case, the **system** objective is to increase the utility factor of the process by storing the excess of production of the **heat source** to later release it to a demand in the **heat sink**.

The boundaries of the **system** are the connections of the heat transfer fluid piping that bypass the normal flow of the process from **heat source** to **sink** to the heat exchanger between the HTF and the molten salts.

The schematic of the process and system boundaries is shown in Figure 1.

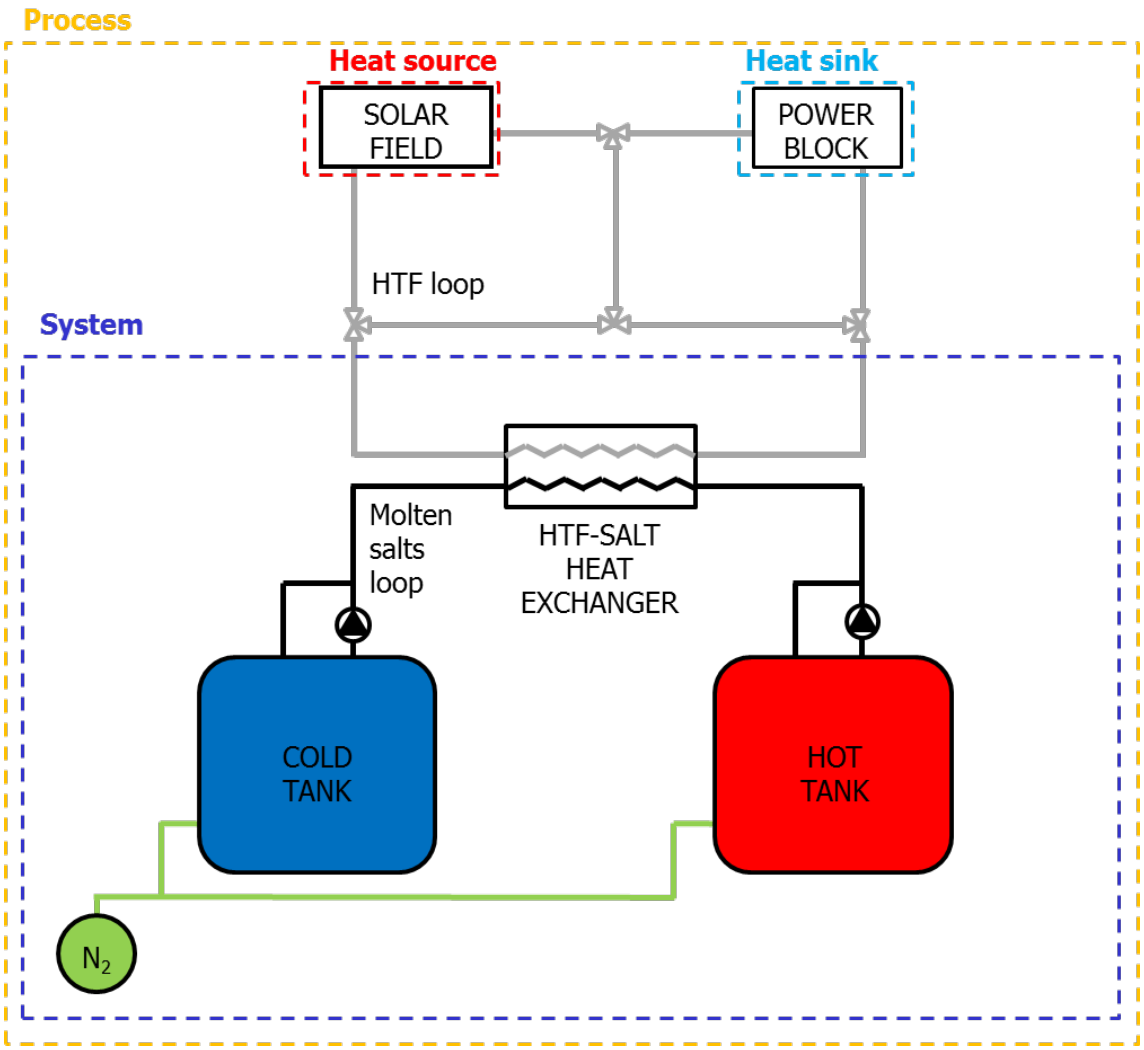

Figure 1. Process and System level of molten salt TES system for CSP.

The **TES system** has three modules, as shown in Figure 2. The objective of the **heat transfer module** is to exchange heat from the HTF of the CSP and the molten salt, hence its main components are the heat exchanger and the molten salt pumps. It connects the two tanks of the **heat storage module**, whose purpose is to store the salt and to minimize the heat losses, avoiding the solidification of the salt. As the molten salt in contact with oxygen can cause corrosion of the components, the **pressurisation module** injects nitrogen into the tanks in order to reduce the amount of air. The summary of the main components of the **system** is presented in Figure 3.

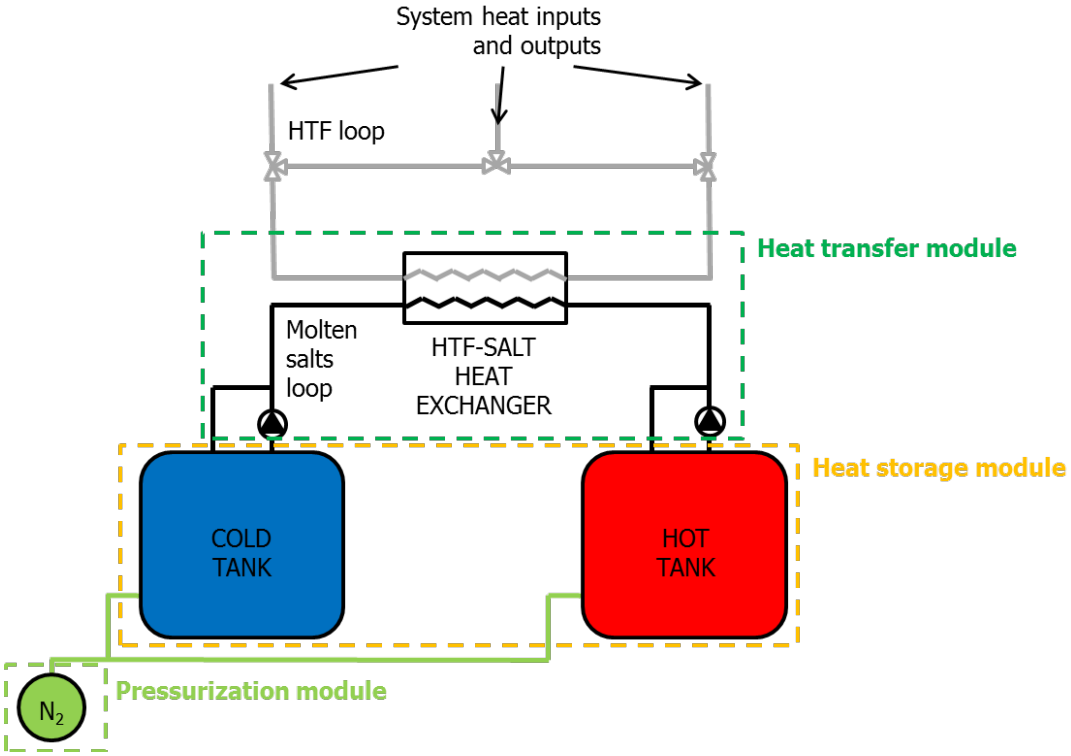

Figure 2. Module level of molten salt TES system for CSP.

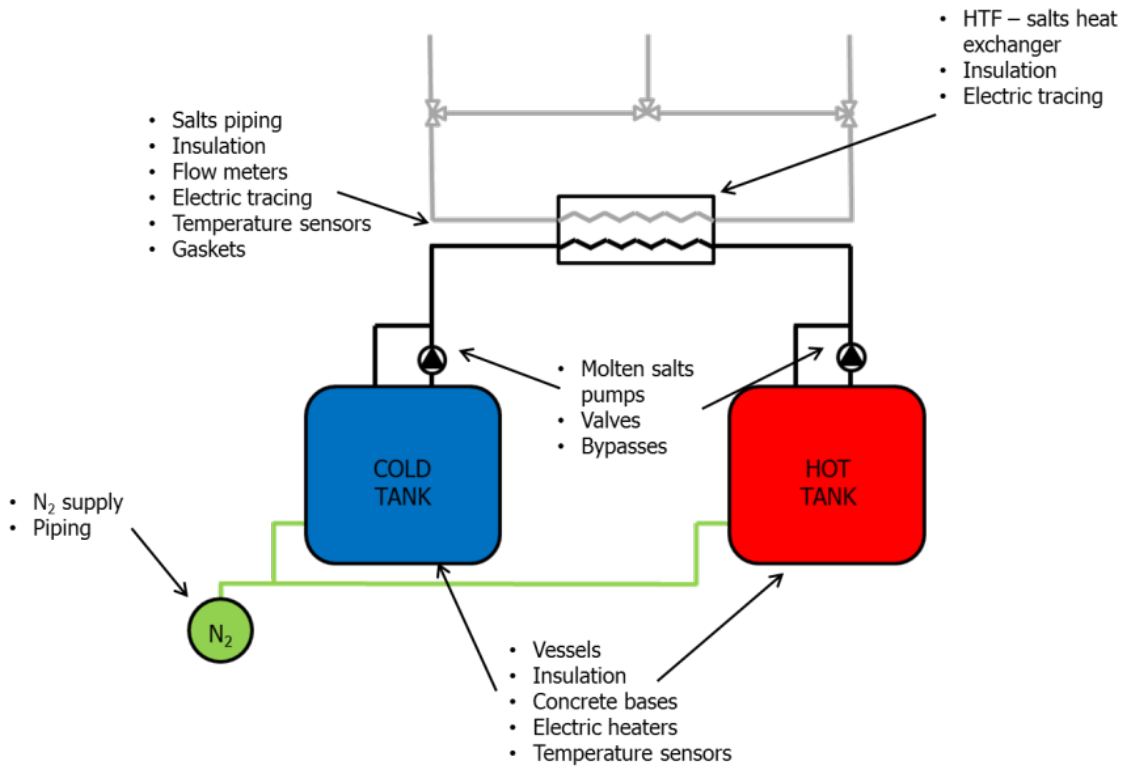

Figure 3. Component level of molten salt for CSP.