



## D6.3 Specifications of the CHEST public tool

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## Glossary, Abbreviations and Acronyms

API	Application Programming Interface
BRP	Balance Responsible Party
CAPEX	Capital expenditure
CHEST	Compressed Heat Energy Storage
COP	Coefficient of performance
DH	District Heating
DHS	District Heating System
DSO	Distribution System Operators
ESCO	Energy Service Companies
EU	European Union
GHG	Greenhouse Gases
GIS	Geographic Information System
HP	Heat Pump
KPI	Key Performance Indicator
OPEX	Operational expenditure
ORC	Organic Rankine Cycle
PV	Photovoltaic
PVGIS	Photovoltaic Geographic Information System
RES	Renewable energy source
ROI	Return on investment
SEMS	Smart Energy Management System
STS	Solar Thermal System
TSO	Transmission System Operators

## Executive Summary

This report is the cornerstone for the development of Task 6.5, which goal is to develop a web tool of economic feasibility of the CHEST system, meant to engage stakeholders across Europe. The present document provides the necessary guidelines to develop the CHEST web tool, like the boundaries of calculation of the performance assessment of the investment on a CHEST system, the intended outputs of calculation, the input variables and parameters that have to be generated as well as the input parameters that are asked to users.

It was established the users will only need to enter basic data regarding the system under study, so that it isn't required any background technical knowledge to use the tool. As default mode, profile curves that can be imported or generated based on location-dependent information, i.e. profile curves of district heating demand, electrical demand and electricity supply of grid-connected systems, are imported or generated without further effort from the user.

When further information is necessary to generate calculation inputs, only steady parameters, such as the maximum power of heat demand or the maximum and minimum limits of the electricity price, are asked to the users.

In any case, it is also offered an advanced option for users that wish to enter manually more precise data.

The calculation engine will set the necessary parameters to dimension the CHEST system components according with the characteristics of each assessed energy system, without interference of the user. It was decided to limit the assessment to two types of energy networks – grid-connected and fully isolated power systems – and only to systems operating in countries of the European Union. It was also established that some of the parameters that characterize the baseline energy system will be fixed by the tool, such as the technical characteristics of back-up systems of stand-alone power networks and other ancillary components.

A very complete set of outputs will be returned. The outputs encompass energy, economic and GHG savings and some more detailed energy balance results. It will be given the possibility to find the conditions for which the CHEST system represents a favorable investment.

# 1. Introduction

## 1.1. Purpose and Scope

The present document describes the work developed for Task 6.4. The goal of Task 6.4 is to define the specifications for the CHEST public webtool that will be developed in Task 6.5. Namely, it is intended to define the scope of calculation and the type, deepness and level of analysis of the outputs that the tool shall return; and the subsequent necessary inputs as well as their sources and level of detail.

The CHEST webtool will be released to allow potential CHEST users to easily and quickly evaluate the feasibility of a CHEST system according to their specific needs and system conditions. The tool will be significant for disclosure and commercial purposes; hence it is crucial to obtain an intuitive tool and to ask for inputs to the user that are not too laborious to obtain. Otherwise, the user may be discouraged and give up on the assessment before finishing it.

The conceptualization of the tool was preceded by the identification of potential users and their needs and interests. This step was fundamental to define how to approach the users and how to define the type of information that is reasonable to ask from them.

In order to identify best practices and errors to avoid aligned with our goals, a preliminary review of similar existing performance evaluation tools was carried out as well.

Along the conceptualization process, proper simplifications of calculation were established as well as the sources and methods of generation of data that can't be directly given by the tool's users.

## 1.2. Structure of the Document

This document is organized as follows:

- Chapter 2 presents an overview of potential users and an overview of performance evaluation tools. This step is the keystone of the tool's conceptualization.
- Chapter 3 describes the scope of the tool, according to the nature of the system for which the integration of a CHEST system is considered. The particular boundaries of each baseline system are also specified in this section.
- Chapter 4 presents the architecture of the tool. First, the structure is described. Then, the inputs asked for the assessment are detailed, followed by the description of the resulting outputs. At last, a flow diagram of the tool is presented.
- Chapter 5 presents the conclusions drawn from this task.

## 2. Overview Users and Performance Evaluation Tools

This chapter presents an overview of the potential users of the CHEST webtool, their background and main necessities and the results of the review of several performance evaluation tools of energy systems that can be found online.

### 2.1. Users of the CHEST Web Tool

It is crucial to know clearly to whom the CHEST web tool will be aimed in order to adapt the type of results obtained to their interests and needs. Besides, the identification of potential users, allows to properly adjust the type of information required by the tool for the assessment, according to the information these potential users may or not possess. From that point forward, it is possible to know the data that have to be generated by the tool to fill the gaps of information left by the user.

The CHEST system is particularly powerful to integrate efficiently several sources of renewable energies, so the most obvious users are renewable energy sources (RES) producers. However, the list of entities that can benefit from the deployment of this system is much wider and accommodates any party that may profit from an enhanced energetic flexibility. Likewise, industries with excess waste heat interested in capitalizing this waste heat also represent an important group of potential users.

The organizations that may be interested in assessing the feasibility of the deployment of a CHEST system, and therefore are potential users of the CHEST web tool, are listed as follows.

- RES producers with particularly unstable production of electricity:
  - Wind farms
  - PV electricity generators
- Energy Services Companies (ESCO)
- Electricity market players:
  - Energy traders
  - Distribution System Operators (DSO)
  - Transmission System Operators (TSO)
  - Balance Responsible Party (BRP)
- District Heating (DH) utilities with thermal storages
- Energy plants with excess heat:
  - Electricity producers, such as waste incineration plants and biomass plants
  - Geothermal plants
- Industries with excess heat:
  - Metal industry
  - Chemical industry
  - Food and drinks industry
  - Pulp and paper industry
  - Non-metallic minerals industry [1]

These potential users can be grouped according to their main necessities.

- The integration of some types of RES in the electricity market is mostly challenged by their intrinsically unstable energy generation. Electricity producers that rely on photovoltaic systems and/or wind turbines are fine examples of suppliers that may



recurrently have peaks and valleys of energy generation that do not match the peaks and valleys of demand. A system that stores energy and manages the input and output of energy from the storage system with a smart optimizer, such as a CHEST system, helps to balance the supply and demand of energy in the most profitable manner and therefore is of the best interest of these RES producers.

- It is in the best interest of ESCOs to have an energy management and storage system that maximizes energy savings for their clients, given that ESCO's profit relies directly on achieving energy savings.
- Players of the electricity market such as energy traders, DSOs, TSOs and BRPs must assure a balanced supply of electricity and, hence, can have an implicit interest for tools and mechanisms that grant a higher control and flexibility of the available energy [2]. This group is less expected to resort to a CHEST system because, according with the European Directive 2009/72/EC, TSOs and DSOs "should not own, manage or, operate energy storage facilities". Nevertheless it is included in the spectrum of possible users, as the same directive foresees that "in exceptional cases the system operators could be allowed to invest in a storage facility, under regulatory approval and oversight, if other market parties are not interested in providing specific storage services, following a transparent market procedure" [3].
- DH facilities require an efficient management of thermal energy to guarantee the supply of low-cost heat. CHEST provides an efficient storage technology. Moreover, CHEST's advanced Artificial Intelligence-based smart energy management system (SEMS) relies in predictive models to accomplish the most efficient storage management and thus allows to obtain a lower thermal energy cost.
- At last, the revalorization of otherwise waste heat can represent a significant income opportunity for energy plants and industries with excess heat that look for balancing out operating costs. Through CHEST's SEMS, their waste heat can not only be capitalized at all, but also, capitalized by the best price possible according with heat demand and prices profiles.

It shall be kept in mind that in spite of the technical nature of these entities' activities, it is possible that the person that may want to evaluate the feasibility of a CHEST system does not have a technical profile. It is more likely that this person has a management or financial controller role instead. This factor is particularly relevant to define the type and level of details of the inputs required by the calculation engine.

## 2.2. Performance Evaluation Tools

It was established that the CHEST web tool must be intuitive in order to seize a spectrum of users as broad as possible, so it is crucial to obtain a tool of easy access, with a neat appearance that suggests simplicity of use and asks for easily obtainable entry-data.

Several evaluation tools of performance available in the market related to heat storage and other types of energy systems were reviewed in order to grasp what kind of information is reasonable to ask from the user, what kind of mechanisms are used in existing tools to facilitate the gathering of information and to provide it with enough flexibility to build a comprehensive tool but not too complex for the user.

This analysis focused mostly on the web tools listed below. The first three tools of the list were developed on the framework of homonymous EU funded projects and the two last ones belong to the United States Department of Energy.

- Indus3Es AHTs Assessment Tool
- HyCool Pre-feasibility Simulator [4]
- RenewIT tool [5]
- REopt™ Lite web tool [6]
- Optimal Sizing Tool for Battery Storage in Grid Applications [7]

The features of these tools that were found to be more interesting from the point of view of the present project, are presented as follows.

REopt™ Lite web tool offers the interesting possibility of assessing the performance of a renewable energy generator system from an economic or from an energy resilience point of view. This option enables each user to obtain results more related with his specific needs and interests.

It was observed that some of the analyzed tools [4] [5] [6] present fields of input data where it is possible for the user to insert more customized information or to opt for approximated data made available by the tool itself according to easily selectable settings. For example, the Indus3Es AHTs Assessment Tool automatically fills the energy cost parameters fields for a given country but it also allows the user to change these values. Similarly, the REopt™ Lite web tool that requires an hourly, half-hourly or quarter-hourly load profile presents the alternative to upload a .csv file with this information as well as the option to choose a profile automatically generated by the tool based on a defined type of building and annual energy consumption, as shown in Figure 1.

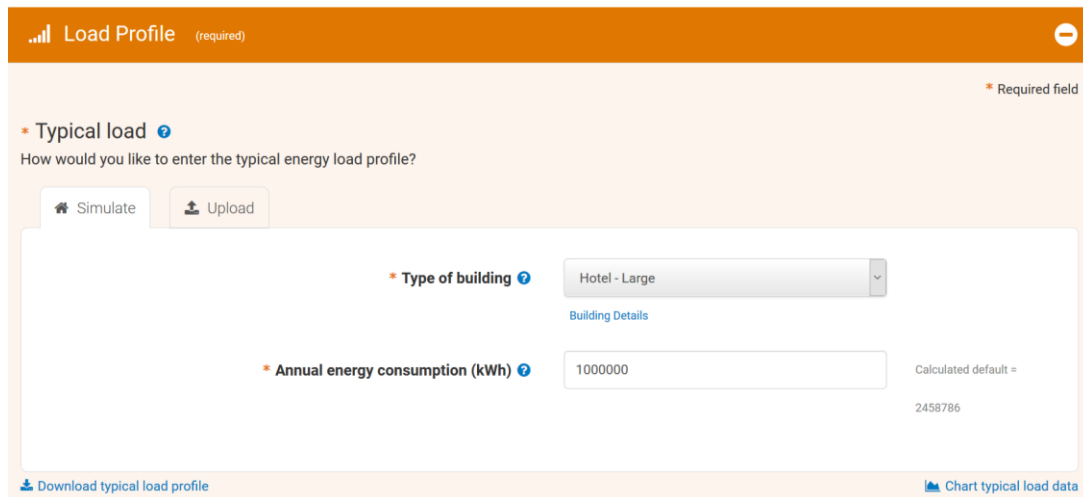
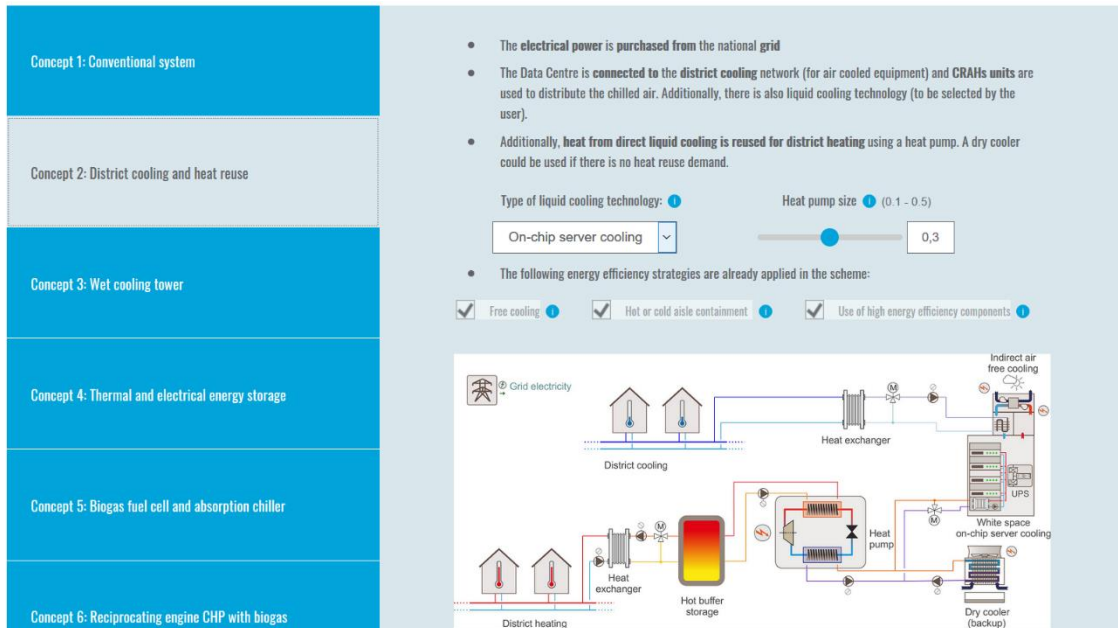


Figure 1. REopt™ Lite web tool – load profile inserting options.

Most of the tools also include “Advanced Options” fields to optionally insert additional information. Implementing this flexibility concerning the input data in the CHEST tool may be valuable to seize both users looking for a quick assessment and users looking for a more

thoroughly feasibility evaluation and willing to invest further time to obtain more accurate results.

The RenewIT tool is built to evaluate the energy and economic behaviour of the implementation of energy efficiency strategies and renewable energy sources of several different types of power and cooling systems. As presented in Figure 2, to organize the input information and ease the definition of the particular system under evaluation, the tool presents pre-filled templates concerning each system. The definitions within each template can be easily adjusted to meet the correct characteristics of the system to evaluate.



**Concept 1: Conventional system**

- The electrical power is purchased from the national grid
- The Data Centre is connected to the district cooling network (for air cooled equipment) and CRAHs units are used to distribute the chilled air. Additionally, there is also liquid cooling technology (to be selected by the user).
- Additionally, heat from direct liquid cooling is reused for district heating using a heat pump. A dry cooler could be used if there is no heat reuse demand.

Type of liquid cooling technology: On-chip server cooling Heat pump size: 0.3 (0.1 - 0.5)

The following energy efficiency strategies are already applied in the scheme:

☒ Free cooling ☒ Hot or cold aisle containment ☒ Use of high energy efficiency components

**Concept 2: District cooling and heat reuse**

**Concept 3: Wet cooling tower**

**Concept 4: Thermal and electrical energy storage**

**Concept 5: Biogas fuel cell and absorption chiller**

**Concept 6: Reciprocating engine CHP with biogas**

The schematic diagram illustrates the energy flow: Grid electricity powers a Data Centre (with Indirect air free cooling, UPS, and White space on-chip server cooling). A Heat exchanger connects the Data Centre to District cooling. District cooling is linked to District heating via a Heat exchanger. District heating is connected to Hot buffer storage, which then feeds into a Heat pump. The Heat pump is linked to a Dry cooler (backup).

Figure 2. RenewIT web tool – energy system setting options.

It was noticed that most of the information required concerns to parameters that specify the baseline conditions of the users' systems which they are expected to know. On the other hand, parameters that can be outside the scope of knowledge of the user, such as the hourly electricity price, are seldomly asked: with the exception of one of the tools [7] that specifically requires to upload a .csv file with these data, all the other tools that work with this information provide the hourly profile based on the location of the user or the average price of electricity. This feature prevents the user to look for information outside the web tool which may lead him to give up on the assessment.

Concerning the design and display of information the following best practices were identified among the reviewed tools:

- When a huge amount of input information is required, it is preferable to divide it in several groups, each of them including a brief explanation regarding the data that is required and their purpose for the calculation. This practice can be seen in the RenewIT web tool, in Figure 2.
- It is useful to position quick informative buttons with complementary explanations next to each field of input data to avoid any ambiguities as exemplified in Figure 3. Limit values for the input data and the respective units shall be presented as well.

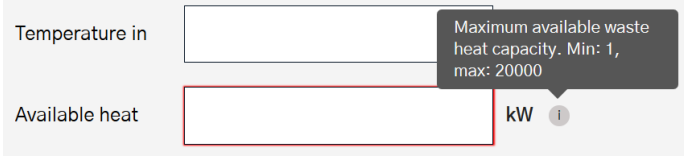


Figure 3. Informative hoverable button from Indus3es webtool

- Additional options are only visible when selected to avoid visual disturbance, as exemplified in Figure 4.

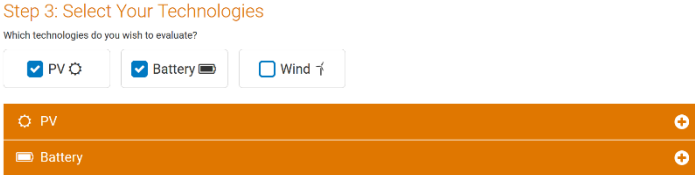


Figure 4. REopt Lite web tool - Visibility of additional options upon selection

- Inserted information is saved and it is possible to quickly access previous groups to change input data without losing the rest of information.
- Results are summarized and presented by subject (e.g. economics or energy). More detailed information can be accessed by the user as well as a summary of the input data. Results can be stored while another scenario is tested for comparison [5] and can be downloaded as a .pdf file.

In order to gather contact data from potential users some tools require previous registration. However, mandatory registration to access the tool can be contraproductive once it may move away some users as well as it involves some legal issues due to data protection regulation.

### 3. Scope

This section defines the general boundary conditions of the tool and specific boundary conditions and assumptions regarding the two types of operation systems that can be analyzed by the tool and how the integration of the CHEST system with district heating is addressed.

#### 3.1. General boundary conditions

The purpose of the assessment tool is to evaluate the feasibility of the CHEST system only. Therefore, the components that compose the existing systems or auxiliary systems will not be taken into account. In other words, RES components and back-up system components costs are out of the scope of the analysis and so they are not included in the calculation.

The tool will be aimed merely for European Union users, once the energy management of the CHEST system is based on the functioning rules of the European electric market and some assumptions and conditions of CHEST operating model may not apply to other locations.

Regarding the nature of the existing energy systems, two possible scenarios will be accepted for assessment:

- Stand-alone power systems, where the CHEST system operates in island mode (e.g. Ispaster)
- Grid-connected, where the CHEST operation depends on generation-demand of the electricity grid and energy market prices (e.g. Aalborg)

Hybrid operation systems, e.g. a stand-alone power system that sells surplus electricity to the grid, will not be considered.

The approach to the assessment of the two enunciated types of systems varies mostly in the treatment of the electricity data. The characterization of heat demand and supply is treated equally for both scenarios.

Regardless of the heat demand system, it is always assumed that heat is provided in the form of liquid hot water.

To ensure the web tool remains user-friendly while still providing useful outcomes, PCM storage capacity and the nominal power of the HP and the ORC will be calculated based on the input parameters that define the operation of the baseline systems.

#### 3.2. Grid-connected systems

Grid-connected systems focus exclusively on systems with a significant availability of residual heat and a considerable heat demand.

For this type of system, it is assumed the electrical supply is entirely provided by the grid. Therefore, it won't be considered self-generation of electricity nor subsequent need for electrical storage or sale of surplus electricity.

The assessment of CHEST systems operating in grid-connected scenarios demands a lower level of detail of information from the user, given that the electrical demand and supply profiles are imported or generated by the tool itself from data of the electrical market of the country where

the grid-connected system operates. Based on the peak and valley electricity prices given as input, the tool will also generate a sinusoidal curve that represents the hourly electricity price profile.

### 3.3. Stand-alone power systems

This category encompasses electrical and/or heating micro-grids completely isolated from external suppliers or consumers. Considering the isolation nature of this type of systems, no external electricity or heat will be purchased nor surplus heat or electricity will be sold. Therefore, it won't be necessary to ask for electricity prices to the users.

For this type of operation system, two options will be given to the user on how to generate electrical demand: standard and advanced. The standard option, which is given as default, is generates the electricity demand profile based on market data, similarly to the grid-connected systems. The advanced electrical demand option can be selected, depending on the detail of information the user retains, so that the curve is generated from the electrical demand profile and the maximum instant power required, as defined by the user.

The electricity production profile is calculated according to the type of RES that integrate the system and their corresponding characteristics. Regarding the types of RES that can compose the electricity production system, it will be possible to add PV and wind turbines. It was decided to exclude electricity production with mini-hydraulic turbines, once it is not possible to easily generate an electricity production profile without asking for too much complex and detailed information to the user about the technology deployed.

For this particular scenario, the operation of back-up systems has to be considered. The back-up system parameters are internally set; thus, it is not necessary to ask for additional information data to the users. By default, the system will reckon on a gas-fired boiler with an efficiency of 90% to assure heat supply and a diesel-generator set with a power factor of 0.8, to prevent electricity shortage.

It is assumed there are no other energy storages but the CHEST system, except for stand-alone cases with heat supply from Solar Thermal Systems (STS), for which a 70 liters tank for each square meter of solar collectors will be considered.

### 3.4. Integration with district heating

If a district heating network is integrated in the power system, there are two options of calculation available: standard and advanced. In the advanced option, the user has to insert the set of information necessary to obtain the heat demand profile, while in the standard option (set as default) the heat demand profile will be generated with climate data, according to the location of the system.

## 4. Architecture

This chapter describes how the tool will be structured and displays the input and output information categories and insertion/exhibition formats. The inputs and outputs descriptions are coupled with illustrative examples from the tool's design mockup.

### 4.1. Structure of tool

The webtool will be available in a dedicated page of the CHESTER project website. In the tool webpage the user will find instructions on how to use the tool and the fields to insert information.

This page will communicate with an API from PVGIS in order to retrieve location-related information. PVGIS is a Geographic Information System (GIS) application that allows to create weather files according to the selected geographic location and to obtain performance results for PV installations, such as the yearly and monthly PV energy production, depending on the entered technical parameters.

As soon as the minimum required input data is collected and the user asks for the assessment results, the page makes a call to the server where the calculation engine of the tool will be hosted. The calculation engine generates the results for the specific case entered and sends the results back to the tool that shows a new page with the web report. At this point it can be given to the user the possibility of changing some of the input data, in order to analyse the impact of those parameters in the outcome. The report can be downloaded in .pdf format.

The schematic structure of the tool is presented in Figure 5.

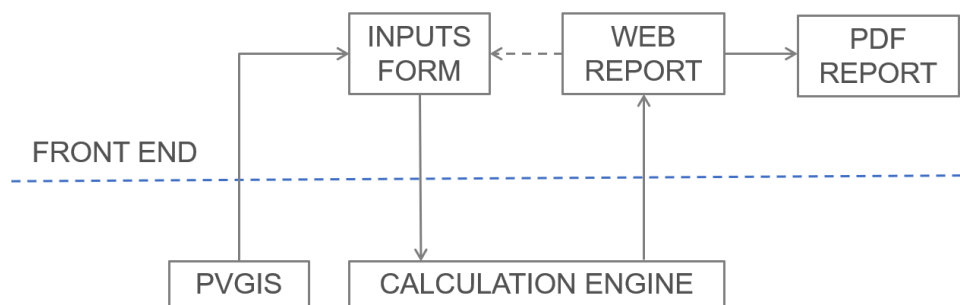


Figure 5. Structure of the tool

The input form will be divided according to the groups of input information described in Chapter 4.2, following the best practices identified in the review of existing performance evaluation web tools in Chapter 2.2.

In order to reach the maximum amount of people as possible, the use of the tool has to be free and easy to access. Hence, it will not be asked any kind of registration to the user.

### 4.2. Inputs

The CHEST system is complex, and it is expected that the users come from a wide spectrum of backgrounds. Consequently, it was decided to provide a number of “fixed” parameters to

simplify the performance assessment and prevent users to disengage before they reach the last step of the tool, while ensuring that useful outcomes are provided. This chapter describes the list of inputs that are required to the user carry out a performance assessment of the CHEST system and presents the other inputs that are prescribed by the tool, in spite of their invisibility in the front end.

Depending on the selected operation mode in baseline definition, some of the inputs have to be inserted by the user or can be artificially generated by the tool, based on the fixed parameters previously mentioned.

The groups of input information necessary are listed below. Each of them will be explained in the following subsections.

- Baseline definition
  - Operation mode
  - Location
- Heat supply profile
  - Type of residual heat source
  - Characterization of the heat source
- Heat demand profile
  - Type of heat consumption
  - Characterization of the heat consumption
- Electricity demand profile
  - Characterization of the electricity demand profile
- Electricity supply demand
  - Type of RES (stand-alone power systems only)
  - Characterization of the RES (stand-alone power systems only)
- Energy prices
- CO<sub>2</sub> emissions

Some fields of input information will offer a default mode in which the input data is generated by the tool based on standard parameters and an advanced mode for users that wish to obtain more customized and accurate results for their specific system.

#### 4.2.1. Operation mode

The model of calculus will vary according with the type of system to analyze. For a matter of simplification for both the user and the developer of the tool, this input will be set by an exclusive option button as illustrated in Figure 6. Selection of operation mode of the baseline energy system.

**Operation mode**

---

☐ Stand-alone power system

☒ Grid-connected system

*Figure 6. Selection of operation mode of the baseline energy system*

Some of the inputs that follow will depend on the option selected at this point.

#### 4.2.2. Location



The user will be asked to select the location of the installation to analyze in a map provided by PVGIS such as the one shown in Figure 7.



Figure 7. PVGIS map to select location

In general, it is necessary to know the country to generate electrical demand and electricity prices hourly profiles and to define country-specific boundary conditions and parameters.

For stand-alone power systems in particular, which rely on climate-dependent energy sources, such as PV generation, STS or wind turbines, the exact location is also necessary to obtain weather data and create hourly profiles of energy production of the sources in question.

#### 4.2.3. Available residual heat

The definition of the available residual heat begins with the specification of type of the residual heat source available. This selection will be made through an exclusive option button, as presented in Figure 8.

##### Residual heat source

- ☒ Waste heat
- ☐ Solar thermal system
- ☐ Biomass

Figure 8. Heat source type

Further characterization depends on the option selected in the previous point. If the available heat consists of waste heat from industrial processes or if it is generated by biomass, it is necessary to enter the maximum temperature and power of the available heat, as shown in Figure 9.

Residual heat source		
Maximum temperature of available heat		°C
Maximum power of available heat		MW

Figure 9. Characterization of the heat source

For “waste heat” and “biomass” options, the daily, weekly and/or annual profile of heat availability may or may not be defined by the user. If the profile is not created, a constant availability of heat characterized by the inserted power and temperature values will be considered.

The default profile definition option consists in a binary system, as shown in Figure 10, in which for each hour of the day (daily profile), day of the week (weekly profile) or month of the year (yearly profile) the user indicates if there is or there isn't available heat.

**Daily profile**

Select hours of availability of residual heat

--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

**Weekly profile**

Select days of availability of residual heat

--	--	--	--	--	--	--

**Yearly profile**

Figure 10. Profile definition

An advanced option is also available for users that wish to specify the percentual amount of available heat in relation with the power specified in the previous point, as exemplified in Figure 11.

▼ **Yearly profile**

Yearly Profile	Value
1	1
1	1
1	1
0.9	0.9
0.9	0.9
0.5	0.5
0.2	0.2
0.2	0.2
0.5	0.5
0.5	0.5
0.9	0.9
1	1

Figure 11. Profile definition - advanced option example

As far as concerns to residual heat sources, in the case of “solar thermal system” the heat profile will be automatically generated as default according to the previously selected location and the area of solar collectors inserted by the user. The remaining parameters necessary for the calculation of the STS energy output will be fixed optimum parameters. If the user wishes to enter more accurate information, some of these parameters, namely the slope and azimuth of the solar collectors, can also be specified.

Residual heat source		
Area of solar collectors	<input type="text"/>	m <sup>2</sup>
▼ <b>Advanced options</b>		
<i>If these fields are not filled, optimized values will be considered</i>		
Slope	<input type="text"/>	°
Azimuth angle	<input type="text"/>	°

Figure 12. STS characterization

The nominal power and efficiency of the heat pump will be calculated according with the profile of available residual heat.

#### 4.2.4. Heat demand

The type of heat demand is defined by the user through an option button, as pictured in Figure 13.

Type of heat demand	
<input type="radio"/>	None
<input checked="" type="radio"/>	District Heating System
<input type="radio"/>	Other

Figure 13. Heat demand type

If there isn't any heat demand, the characterization of the heat profile is complete at this point with the selection of the "None" option.

On the other hand, if the CHEST system is meant to be integrated with a District Heating network, the heat profile can either be automatically generated, which is the default setting, or it can be customized by the user. In the latter case, the user has to provide the same additional information as the one necessary to define the heat demand of the "Other" option.

The "Other" option concerns to any other heat demanding process integrated in the system at stake. The required data consists of the maximum instant power of heat required by the system and the corresponding temperature of supply and return, as shown in Figure 14.

Heat demand definition		
Temperature of supply	<input type="text"/>	° C
Temperature of return	<input type="text"/>	° C
Maximum instant power required	<input type="text"/>	MW

Figure 14. Heat demand characterization

The profile of heat demand can also be considered constant or defined by the user. The available profile definition options for this category are the same as for the definition of the profile of available heat, as described in section 4.2.3.

#### 4.2.5. Electricity demand

As mentioned in section 3.2, the electricity demand profile of grid-connected systems is automatically generated based on information about the electricity market. This procedure may be applied to obtain electricity demand profile for stand-alone power systems as well, if the default settings are accepted. Otherwise, the user has to enter further information to define a more detailed electricity demand, in particular the maximum instant power required and the demand profile, as displayed in Figure 15.

[illegible]

Figure 15. Advanced settings for electricity demand characterization for stand-alone power systems

For further information on profile definition options, refer to section 4.2.3.

#### 4.2.6. Electricity supply

Electricity supply of grid-connected systems is also characterized by the tool based on information about the electricity market of the selected country.

On the other hand, the definition of the electricity supply profile of island-type systems is slightly more laborious for the user. To begin with, the type(s) of renewable electricity sources that compose the power system in question have to be selected, as pictured in Figure 16.

**Renewable electricity source**

- ☐ PV system
- ☐ Wind turbine

Figure 16. Renewable electricity source selection

The energy output of all the available options for RES are weather-dependent. Weather data will be retrieved from PVGIS according with the previously selected location.

The electricity production profile of wind turbines is generated through hourly wind speeds and air characteristics obtained from the weather file along with the number of turbines deployed and their nominal power given by the user, as shown in Figure 18.

Wind turbine production settings		
Number of turbines	<input type="text"/>	units
Nominal power	<input type="text"/>	kW

Figure 17. Characterization of wind turbines

For the specific case of PV systems, the characterization of the energy source will be carried out entirely with PVGIS API. The input data required from the user is shown in Figure 18. Fields within the blue rectangles must be necessarily inserted by the user. The remaining fields, will contain default values that the user can edit or informative buttons suggesting average values, to prevent the user from giving up on the analysis in the case he does not possess this information.

Solar radiation database*	<input type="text"/>
PV technology*	Crystalline silicon
Installed peak PV power [kWp]*	1
System loss [%]*	14
<b>Fixed mounting options</b>	
Mounting position*	Free-standing
Slope [°]*	35
Azimuth [°]*	0
	<input type="checkbox"/> Optimize slope <input type="checkbox"/> Optimize slope and azimuth

Figure 18. PV system characterization parameters

#### 4.2.7. Energy prices

For grid-connected systems, the valley and peak electricity prices of the day-ahead electricity market will be asked, as presented in Figure 19, to generate a profile to represent the daily electricity price for the whole year based on a sinusoidal curve pre-defined with market trend data.

Electricity price	
Insert maximum and minimum values of the day-ahead electricity market	
Peak electricity price	<input type="text"/> €/kWh
Valley electricity price	<input type="text"/> €/kWh

Figure 19. Input for electricity price profile generation

Since there isn't any other fuel-consumption foreseen for grid-connected systems, this data shall suffice.

As aforementioned, the electricity price is not required for stand-alone power systems since there will not be any trade of energy beyond the boundaries of the system. The fuel-related costs to of heat producing or back-up systems will be prescribed by the tool, linked to the country of operation of the system.

#### 4.2.8. CO<sub>2</sub> emissions

The amount of CO<sub>2</sub> emitted due to energy generation to meet the demands of a certain system depends on the type or types of fuel used to produce that energy. By its turn, the type of fuel employed or the energy mix of electricity production vary from country to country. To avoid asking to the user for this information, the conversion factors to obtain CO<sub>2</sub> emissions will be retrieved by the tool according to the country where the CHEST system is implemented.

### 4.3. Outputs

The outputs that will be presented by the tool are described in this section.

The web tool calculates yearly and monthly outcomes regarding energy usage, storage and savings and the resulting economic balance. To do so, a prior dimensioning calculation is carried out, so the characterization of the CHEST system for each analyzed scenario can also be provided.

Given that the preliminary results show that the CHEST systems may not be financially feasible without correct subsidies in place, the results will focus on the performance and yield of the CHEST system. Thus, the user can, in a post-processing stage, couple these outputs with local conditions and subsidies available to assess the feasibility of the CHEST system.

It is not yet fully closed if the financial results will consist in KPI results and investment costs for the given conditions, or if the set of conditions for which the CHEST system may be a promising investment will be presented instead.

In short, the outputs returned by the tool will be grouped as follows:

- Energy balance results
  - Yearly electrical energy savings [MWh]
  - Yearly thermal energy savings [MWh]
  - Monthly electrical energy savings [MWh]
  - Monthly thermal energy savings [MWh]
  - Monthly energy (heat/electricity) absorbed by the HP [MWh]
  - Monthly energy (heat/electricity) produced by the ORC [MWh]
  - Monthly thermal energy stored and supplied by the PCM [MWh]
  - Monthly energy supply share of each energy system [%]
  - Yearly energy supply share of each energy system [%]
- Environmental balance
  - Yearly GHG savings [t]
  - Monthly GHG savings [t]
- Financial indicators and results
  - Yearly savings [€]

- Monthly savings [€]
- and**
- Total investment [€]
- Return Of Investment (ROI) [years]
- Internal Return Rate (IRR) [%]
- or**
- Competitive CHEST CAPEX [€]
- Favorable electricity market conditions [€/MWh]
- CHEST technical parameters
  - Heat Pump nominal power [MW]
  - Heat Pump COP [%]
  - Organic Rankine Cycle Turbine nominal power [MW]
  - ORC turbine efficiency [%]
  - PCM capacity [MW]
  - Overall energy efficiency of the system [%]

Each of these groups will be further explained and exemplified in the following sections. It shall be mentioned that the examples presented are merely illustrative and therefore don't represent results of an actual CHEST assessment.

#### 4.3.1. Energy balance results

Yearly and absolute results will be displayed in a first plan, namely, yearly savings of energy, highlighting CHEST system's potential to deliver significant electrical and thermal savings to energy networks through its smart storage-supply management system.

In order to not overwhelm the user, results broken down by shorter timespans and by types of system and components, such as the ones exemplified by Figure 20 and Figure 21, will be presented separately for further analysis.

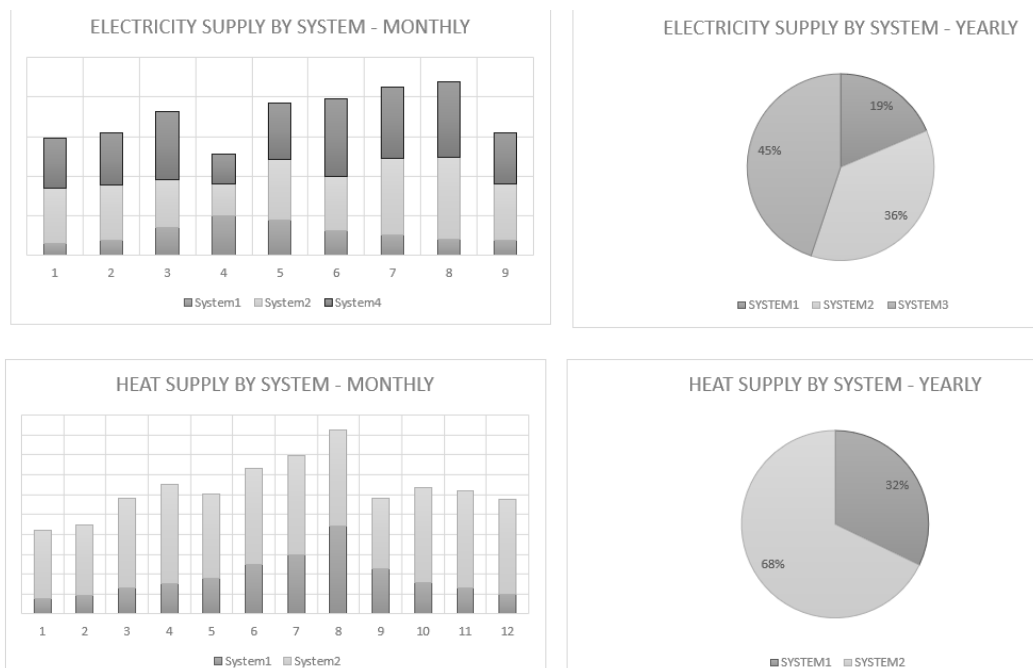


Figure 20. Monthly results broken down by system share - example

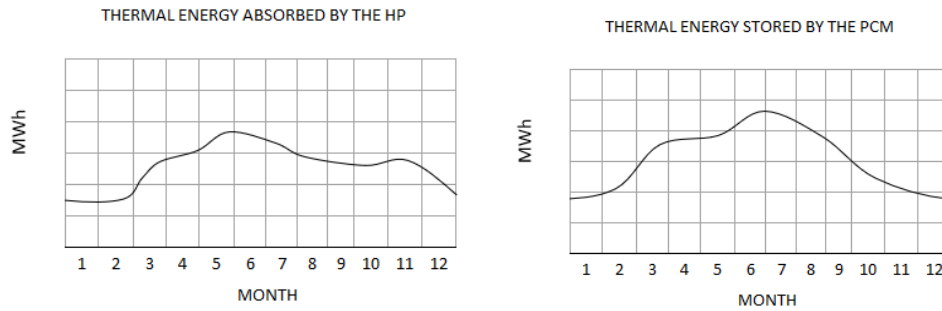


Figure 21. Monthly results for two components - example

#### 4.3.2. Environmental results

This section of results will present the comparison between GHG emissions due to the operation of the baseline energy system with and without the integration of the CHEST system and the resulting emissions avoidance. It will also be provided both global yearly results and monthly results of each system.

#### 4.3.3. Financial indicators

Within the financial results group, firstly, it will be given emphasis to the yearly economic savings provided by the CHEST system operation, as exemplified in Figure 22.

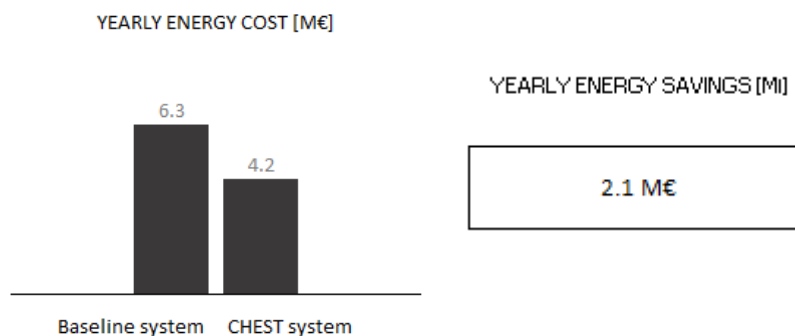


Figure 22. Yearly savings result - example

From the lessons learnt in T6.2, poor financial feasibility results are expected for the CHEST system. Two options can be considered regarding the type of financial results to deliver:

- 1) The ROI and the IRR are presented as output, as well as the initial investment for the dimensioned CHEST system. In this case, IRR and ROI results will be coupled with the reminder that local subsidies, that may impact significantly the feasibility of the investment, were not included in the KPI's calculation. Once the first results are obtained, it will be offered to the user the possibility of exploring the impact of the variation of electricity market, by changing the originally established electricity price limits as shown in Figure 23. Additionally, after the calculation of the first results, the user can opt to recalculate after including a percentage of subsidies over the CAPEX that



may be available for his specific situation. Thus, if the investment isn't favorable for the given initial conditions of calculation the user can find the conditions for which the integration of a CHEST system becomes cost-effective.

### Electricity price

Use the slider to visualize how the electricity price variation affects the results

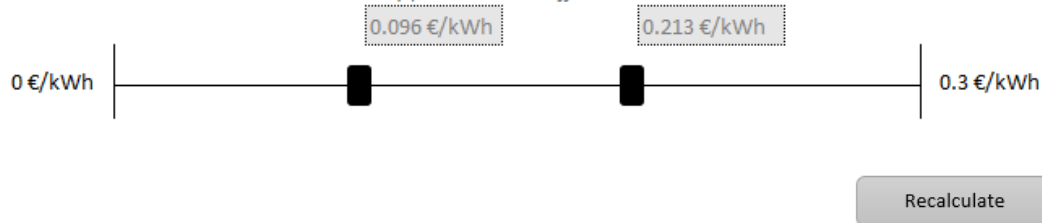


Figure 23. Electricity price limits slider

- 2) Alternatively, the set of conditions for which the CHEST systems turns out to be a competitive investment, such as the technology price and the electricity price, can be given instead.

#### 4.3.4. CHEST technical parameters

As a bonus, the tool will deliver the characteristics of a customized CHEST system for the specific case analyzed. The dimensioning results will include the HP and ORC nominal powers and COP, as well as the required PCM capacity for the system under study. The resulting overall efficiency of the CHEST system will also be presented. The overall CHEST efficiency is represented by an indicator suitable to the technical features of the system previously established in T4.3. This resulting overall energy efficiency considers both electricity and heat, i.e. it relates to the useful energy output (electricity and heat) of the CHEST system to the input of energy (electricity and heat) into the CHEST system. A detailed definition of the CHEST system overall energy efficiency can be found in D4.3.

#### 4.4. Flow diagram

This section presents a flow diagram of the tool revealing the number of data input steps required.

Each group of input information, identified by the right-sided blocks of Figure 24, will be presented to the user in separate pages or sections. The section concerning the baseline definition is repeated in the flow diagram to intuitively display the dependences of both the "Generation of the heat availability profile" section and the "Generation of the electricity production profile" section on the baseline parameters defined in the first page. Nevertheless, the definition of this group in the web tool will only be asked once, at the beginning of the assessment.

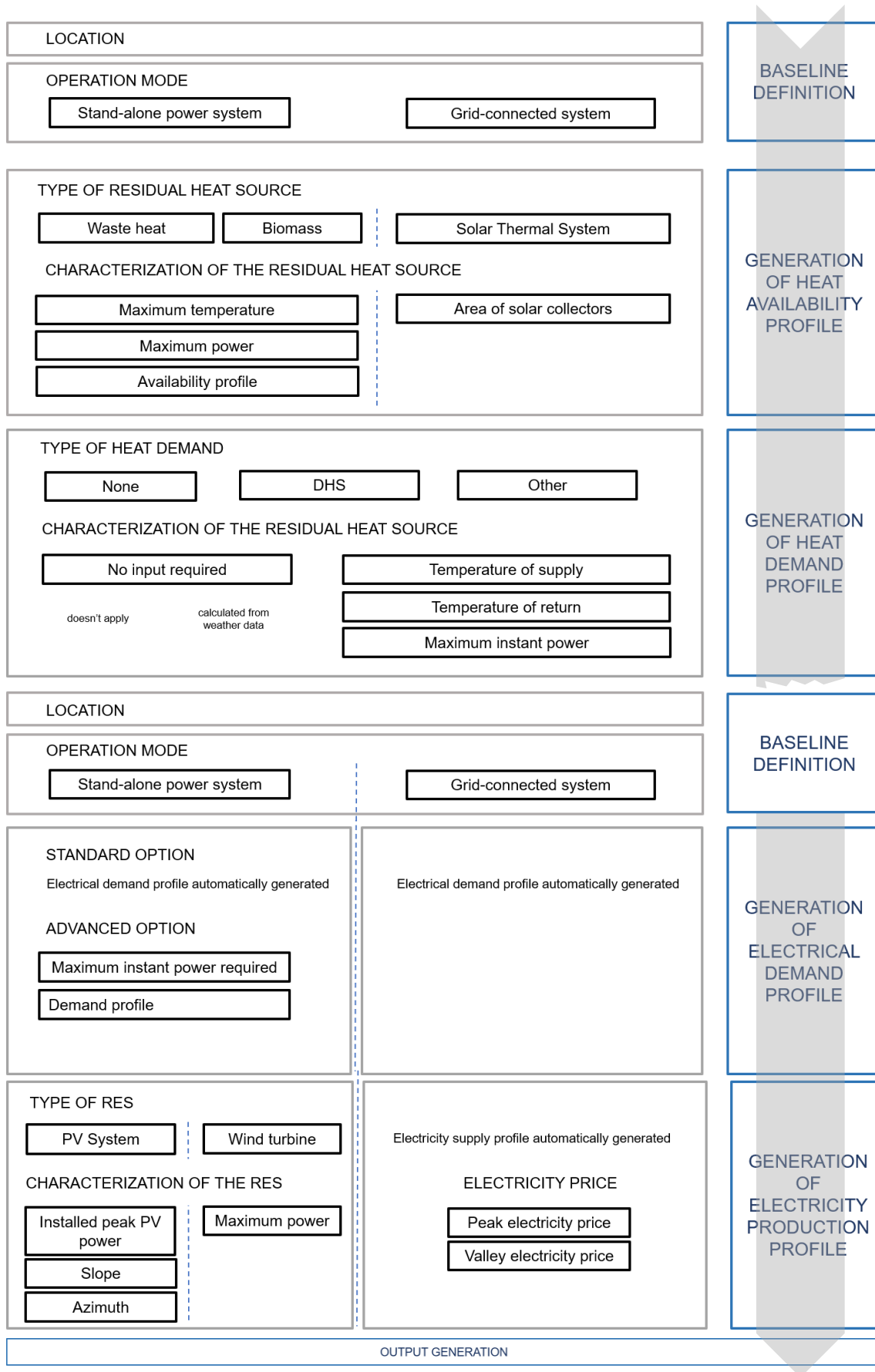


Figure 24. Flow diagram

## 5. Conclusions

The main efforts of the tool conceptualization were focused on making it as user-friendly as possible. It was realized that to accomplish it, a lot of parameters and variables necessary to obtain feasibility assessment results have to be imported or generated by the calculation engine. Thus, the most significant challenge of the task befell on finding an acceptable mid-point between the realistic amount of information that can be asked to a user and the necessary level of detail of that information so that a specific, real system can be properly represented. Both factors had to be balanced with the fact that the complexity of the calculation engine must be limited for a matter of calculation time.

The considerations taken along the development of Task 6.4 will produce a tool able to conduct reasonably customized feasibility assessments of the CHEST system without overloading neither the user, the calculation engine nor the tool developer.

Based on the conclusions from Task 6.2, it is expected that for some cases the performance assessment of the investment on a CHEST system will reveal it unfavorable, given the current electricity prices and technology CAPEX. The tool may demonstrate if (and how) an initially poor investment performance assessment can be counterbalanced by the variation of the electricity price and/or investment subsidies or the CHEST technology cost. This exercise allows to know the favorable conditions for an investment in a CHEST system for a certain energy system.

This document sets the ground for Task 6.5: it provides the general guidelines for the development of the task while at the same time, it does not fully close some work procedures, such as specific methods of profile generation or the tool's design and aesthetics, to allow a certain degree of freedom in the development of the tool in Task 6.5.

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