Storage-LCA Tool: User guide

Content

List of abbreviations

LCA	Life cycle assessment
LCIA	Life cycle impacts assessment
PCM	Phase changing material
TCM	Titanium composite material
GWP	Global Warming Potential
PEtot	Total Primary Energy
PENRT	Primary Energy not renewable total
PERT	Primary Energy renewable total

Introduction

This Userguide helps you understanding the functionality, structure and application of the **Storage-LCA Tool**. The tool constitutes the result of the German funded project *Environmental Evaluation of Selected Storage Materials and Concepts for Heating and Cooling Applications (Speicher-LCA)*, funded by the Federal Ministry of Economic Affairs and Energy (BMWi).

The tool shall be understood as software tool for decision makers by providing scientific support in the selection of environmental suitable thermal storage materials and concepts within building application (*Figure 1*) on the basis of life cycle assessment (LCA). Comprehensive environmental balances based on the LCA software GaBi ts have been integrated on material, component and concept level. Hereby, sensible, latent and thermochemical storage concepts have been analyzed, accompanied by simulations on the energetic performance.

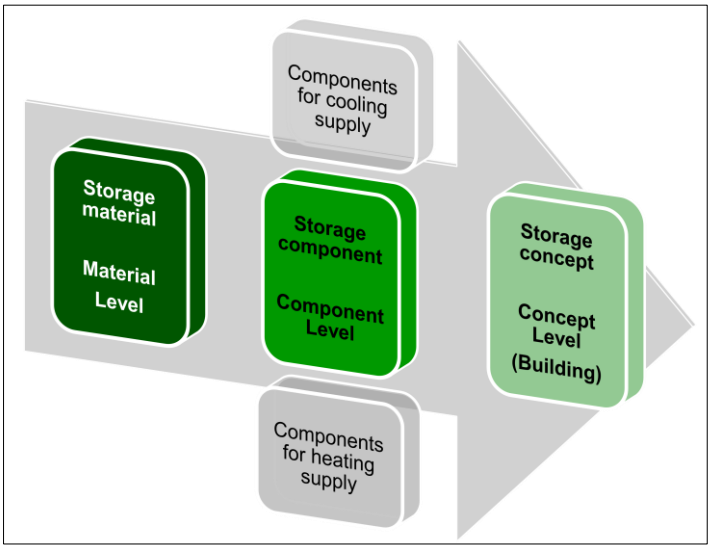


***Figure 1*: Environmental assessment levels**

Two modes, a basic and an advanced one, have been distinguished (*Figure 2*).

Within the ***Basic Mode*** the user is able to perform comparisons for storage materials at predefined working temperatures. Furthermore, a simplified analysis of innovative storage system layouts on building level can be conducted and compared with a reference system. This analysis is based on default storage components/combinations as well as default energetic simulations.

Within the ***Advanced Mode***, default storage components and systems can be customized individually and analyzed. In addition, individual energy demand simulations may be integrated and more detailed analysis may be performed.

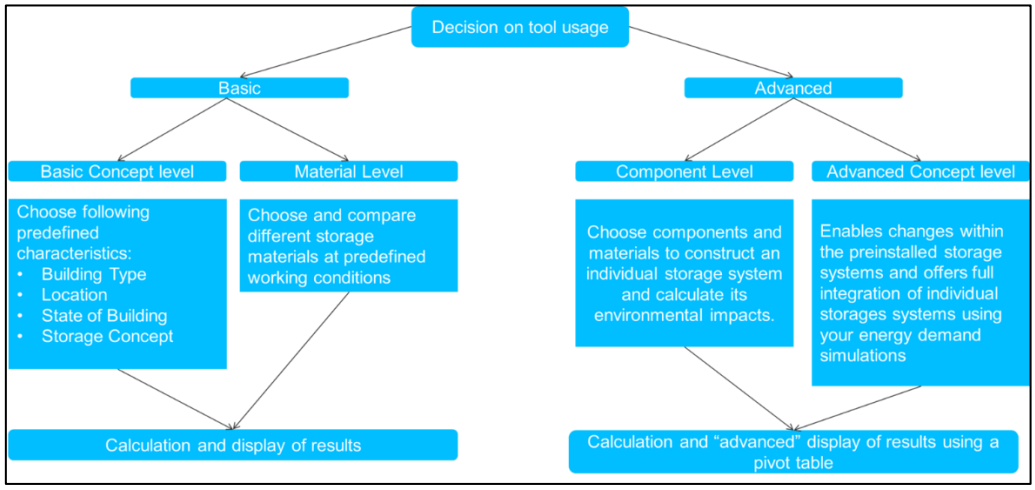


Figure 2: Overview on Storage-LCA Tool functionality and methodological background

Both Basic and Advance modes are based on a methodological approach, here below represented in *Figure 3*: in a preliminary stage a database containing LCIA analyses results of main materials and components is produced. By describing the technical features of the system, the user selects material and components from the database. Many declared units and values may be subjected to a transformation in order to carry out a final Life Cycle Impact Assessment with declared unit and values. The final results are presented in a clear and comprehensive form, with help of tables and graphics.

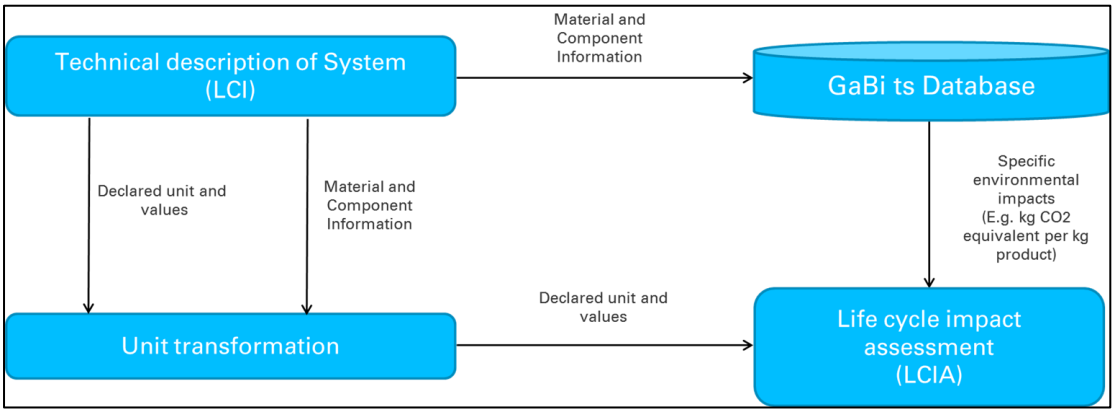


Figure 3: Methodological approach for LCA

Please note:

By clicking the button "Info Userguide", the user can view the chapter of this Userguide, which explains in details the selected spreadsheet.

Remarks on LCA analyses

The LCA (Life cycle assessment) analyses have been carried out with help of GaBi software in according to the standard ISO 14040-14044. For the specification of building- component level the following information have been taken into account:

- **DIN EN 15804**: Sustainability of Buildings – Environmental Product declarations - Core rules for the product category *of* construction products;
- **DIN EN 15978**: Sustainability of construction works - Assessment of *environmental* performance of buildings - Calculation method;
- **DIN EN 15643-**2: Sustainability *of* construction works –. Assessment *of* buildings –. Part 2: Framework for the assessment of the environmental quality;
- **EeBGuide (EU-FP7**): Operational Guidance for Life Cycle Assessment Studies of the Energy Efficient Buildings Initiative.;
- **ILCD Handbook**: The International Reference Life Cycle Data System.

The specifications of LCA analyses are available in further publications[1]; here below a quick overview on system boundaries and functional unit is provided.

- Since different subsystems are defined, a common **functional unit** cannot be given: however, the tool is conceived in order to carry out analyses into the higher-level system without conversion steps.
  By *material properties* a "Declared Unit" is established and scaled by the mass of the storage material [kg]. This means that the specific storage capacity in [J / kg] of the respective storage material is included in the evaluation of the storage component. Their function is a time, namely the stored thermal energy [kWh]. At the *concept level*, a storage component is used as an element for heat and / or cooling supply and coupled with other systems for energy supply. The assessment at the conceptual level is based on the functional equivalences [m² NGF * a].
- The tool focused mainly on the ***constructional aspect*** of the selected product, i.e. how is the material/product is produced (A1-A3, see *Figure 4*) as well as its End of Life (C + D phases). This, in order to evaluate the own product value, by excluding how it would be used during its service life. On building concept level, analyses may include energy consumption due to usage (B6 phase). B4 phase is so far neglected, but may be implemented in future improvements.

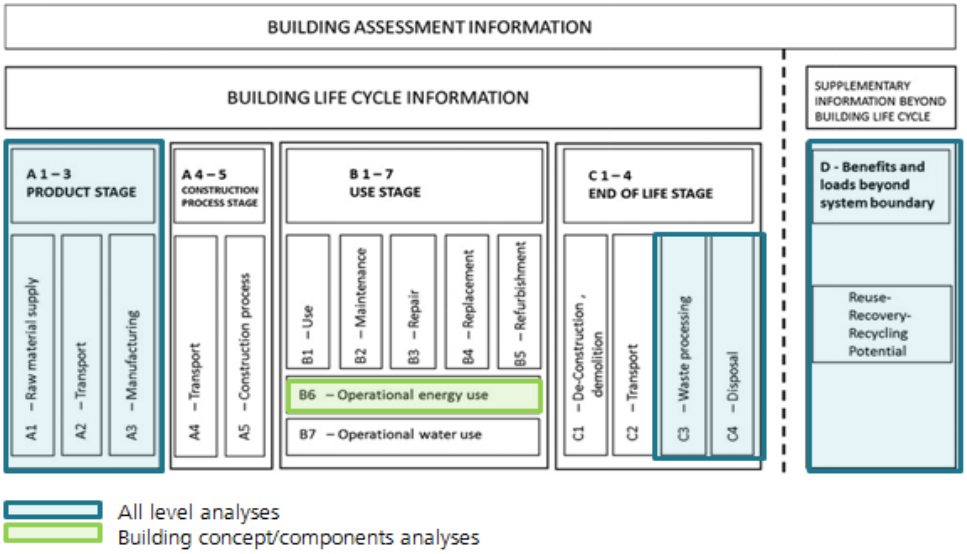


Figure 4

[1] K. Lenz, R. Horn: "Anforderungen und Methodik für die ökobilanzielle Bewertung ausgewählter Speicher Konzepte"

A. Basic Mode

The basic mode offers following options for assessment:

- *Option 1*: Storage material comparison (based on predefined working temperatures)
- *Option 2*: Analysis of innovative storage system layouts (based on default storage components and their combinations) and comparison with a reference system

Once enabled its contents, the tool will address the users automatically to a start page, in which the preferred option can be selected (see *Figure 5*).

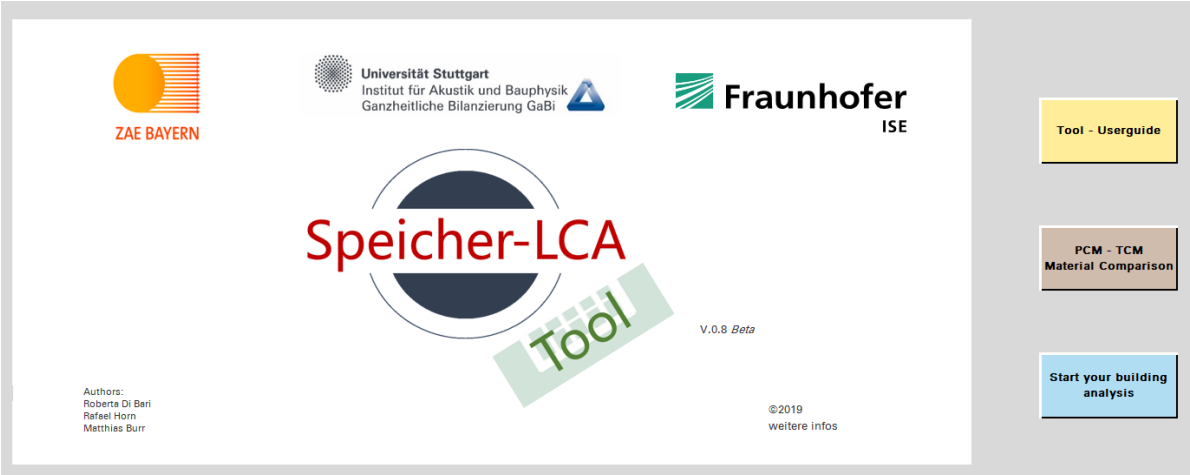


***Figure 5:** A screenshot of the Tool's start page.*

I. Material comparison

Performing general settings

1. Enter from the start page the button "*PCM-TCM Material Comparison*" (see *Figure 6*). The user will be addressed to the spreadsheet "*Material Comparison*". If a comparison among 3 materials is to be conducted, the button "*3rd Material*" adds a further box.

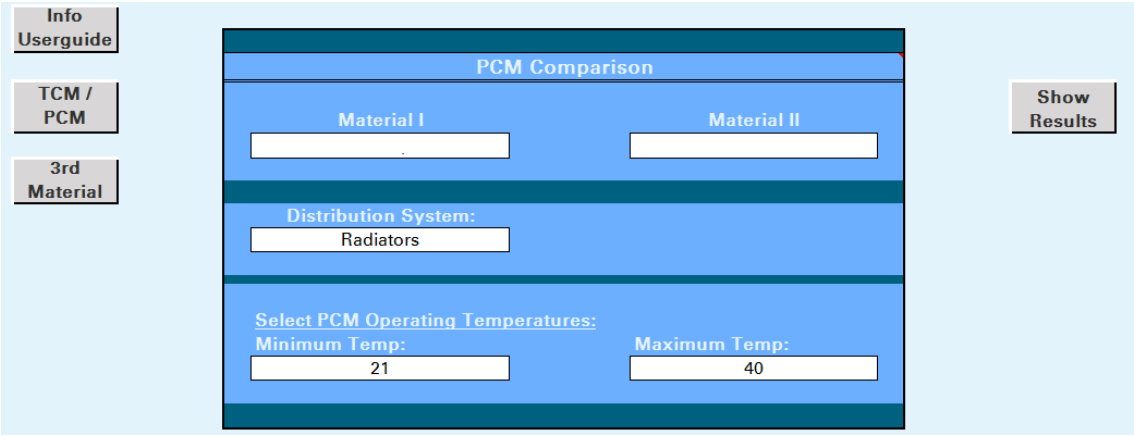


***Figure 6:** Main screen of "Material Comparison" Spreadsheet*

2. Click the button "*TCM / PCM*" (*Figure 7*): to choose the material class within which you want to compare storage materials. The input mask will change accordingly.

Please note: by switching between PCM and TCM, former information defined within the input mask will be deleted.

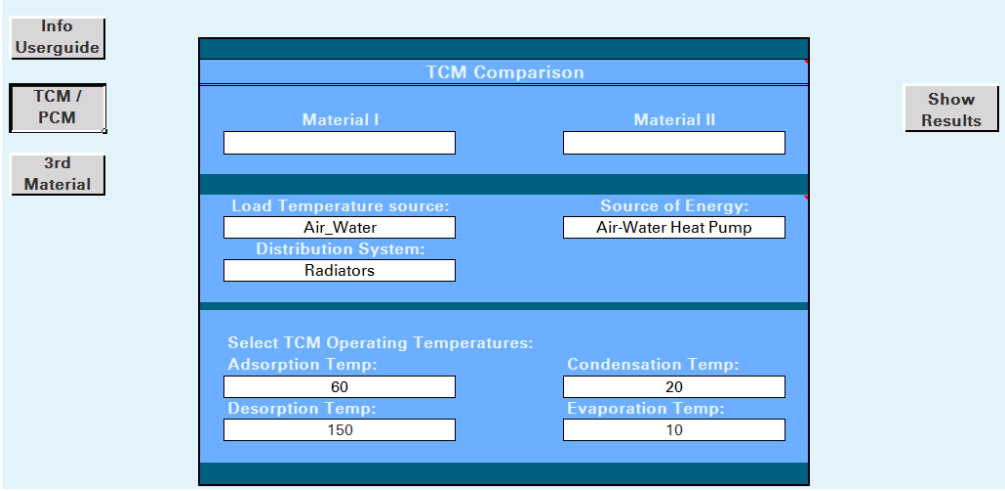


***Figure 7*: TCM input masks.**

3. Choose the materials (*Material I, Material II, Material III*) you want to compare by selecting them from the drop-down menu (*Figure 8*).

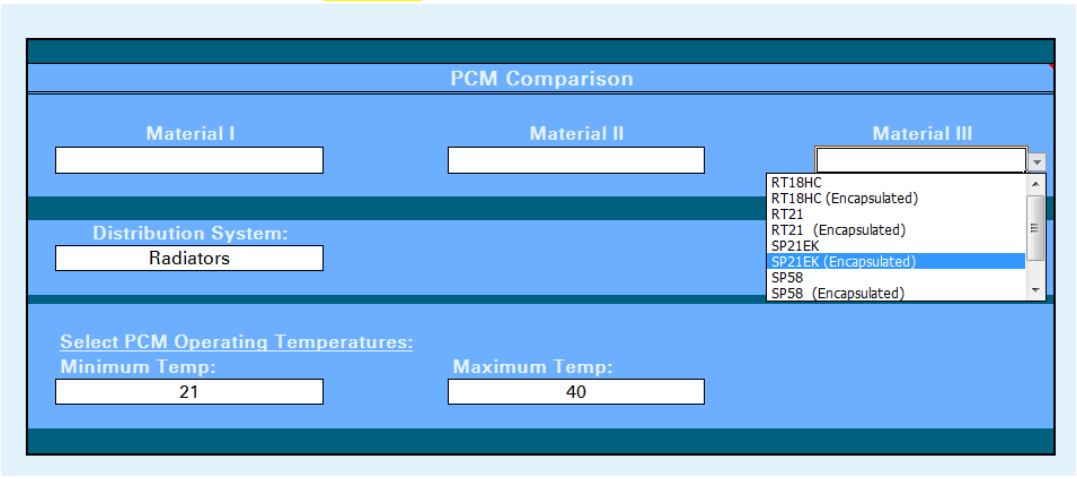


***Figure 8*: Material selection via Drop-Down Menu**

The available PCM and TCM materials in database are the following in *Table 1*

PCM	TCM
RH10HC	CAU-10-H (powder/pellets)
RH11HC	SAPO-34 (powder/pellets)
RH18	Silica gel (macroporus)
RT18HC (Encapsulated or not)	Zeolith 13X (powder/pellets)
RT21(Encapsulated or not)	Y-Zeolith (powder/pellets)
RT24 (Encapsulated or not)	Zeolith-LiX (powder/pellets)
RT62HC (Encapsulated or not)	Al-Fumarat
SP15 (Encapsulated or not)	Cu-BTC (powder/pellets)
SP21 EK (Encapsulated or not)	MIL-101(Cr) (powder/pellets)
SP58 (Encapsulated or not	Z-4A (powder/pellets)
Sodium acetate (Encapsulated or not)	Salts hydrated (LiBr, CaCl2, NaOH)
Generic Parafin	

***Table 1*:PCM and TCM available materials**

4. Define the operating temperatures in °C as follows:

PCM	TCM
Minimum Temperature	Adsorption Temperature
Maximum Temperature	Desorption Temperature
	Condensation Temperature
	Evaporation Temperature

***Table 2:** Temperatures to be defined for material comparison*

By varying the operating temperatures, the results for analysis will change accordingly.

In case you are not able to provide detailed operating temperatures, select from the default menu for "*Distribution System*" (PCM/TCM Material), "Load Temperature Source„ and "Source of Energy" (only TCM Materials). The nearby table will indicate *default operating temperatures*. If some of the values are out of default range, a warning message will help the user (see *Figure 9*).

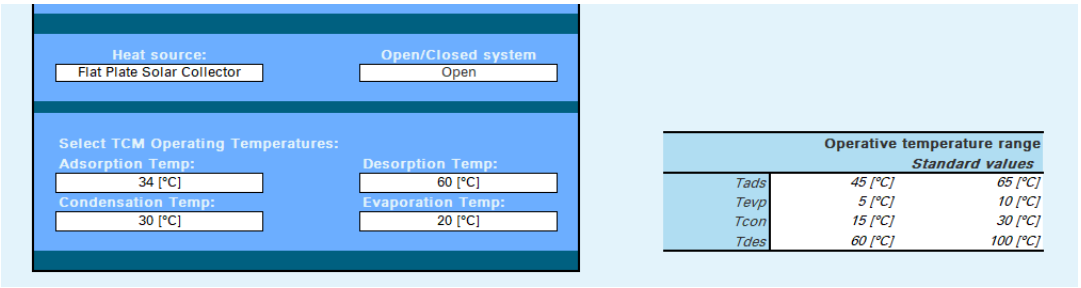


***Figure 9:** Operative standard temperature range for the selected source of energy distribution system*

Possible options are shown within following *Table 3*:

Ambient heat sink/source	Heat Temperature Source	Distribution System
Soil	Geothermal	Underfloor Heating
Air	Vacuum Tube Solar Collector	Cooling Surface
	Flat Plate Solar Collector	Radiators
	Air-Water Heat Pump	

***Table 3:** Source of energy and distribution system covered in tool*

Result presentation and analysis

1. Select the button "*Show Results*" to enter the results for comparison.
2. By clicking the button "*Input Screen*", you are able to switch back to the input mask.

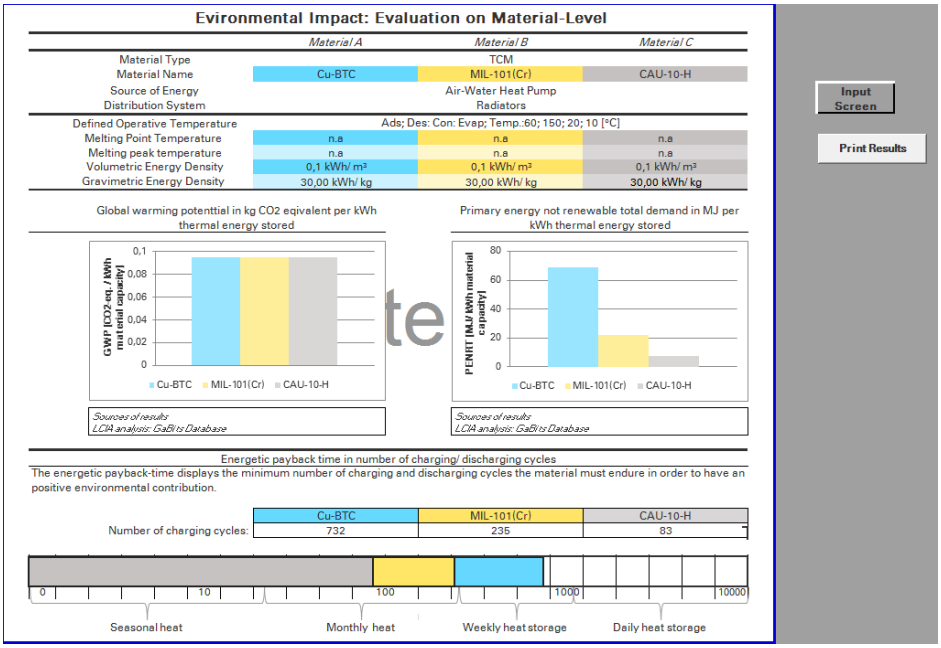


***Figure 10*: Results screen of a comparison among 3 PCM materials**

Results are displayed numerical and graphical (*Figure 10*), which are:

- **Product/material properties** (temperature ranges, energetic densities, …)
- **Environmental analysis** (GWP, PENRT)
- **Energetic payback time** in number of charging cycles: in according to this, the heat storage is seasonal, monthly, weekly or daily (best case).

The spreadsheet layout is a printable page. By clicking on "Print Results", the toll will addresses the users directly to the print preview.

II. Simplified analysis for innovative storage concepts/systems and comparison with a reference

For building analysis, please press the button "*Start your building analysis*" on start page.

The user will be addresses directly to the spreadsheet "Basic concept information". Such spreadsheet is composed by a **mask** and a **navigator** (see *Figure 11*): the mask reports all the specifications required for the analysis; the navigator (here highlighted in red) will guide the user to results and to further spreadsheets. In the navigator are specified the functions available for all user and the ones only for experts.

If you are not an expert user, please click on the button "*Basic Mode*". On the top of the spreadsheet "Basic Mode", now appears and all the expert functions are locked.

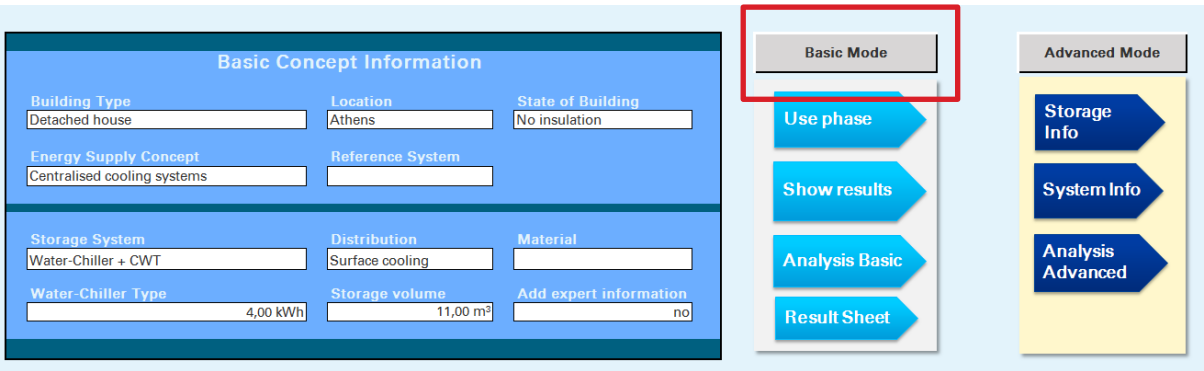


***Figure 11**: A screenshot of the spreadsheet "Basic Concept Information"*

Performing general settings: Basic concept information

1. Enter the spreadsheet "*Basic Concept Information*" and choose (via the Drop Down menu, see *Figure 12*) the desired building type, location and energetic state of the building, within which you want to analyse a storage concept.
   Please note the available combinations here in Table 4. If the combination entered is not available, a warning message will notify the user.

Location	Helsinki	Strasbourg	Athens
Building Type	Detached House Apartment building Office block		
State of Building	Moderate insulation Energy efficient building	Little insulation Moderate insulation Energy efficient building	No insulation Little insulation Moderate insulation Energy efficient building

Table 4

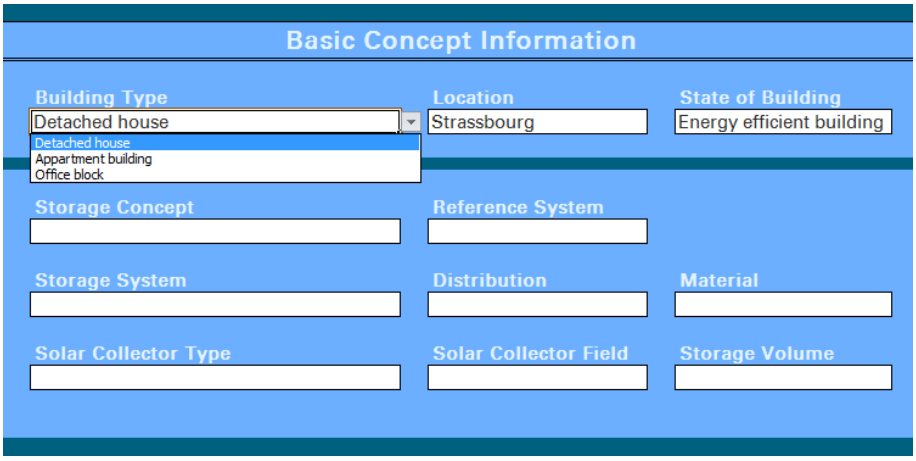


Figure 12: Basic concept Information input screen. Building type definition

2. Define the general *building supply concept* and specify your reference system for building supply.

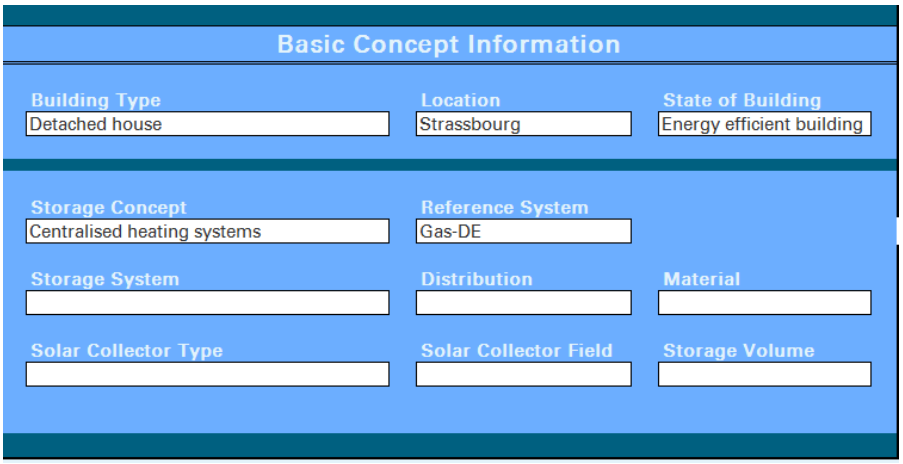


Figure 13: Basic concept Information input screen. Storage concept and reference system specification

3. Define the storage system layout. Available default combinations (depending on the building location, type and energetic state) are:

Supply concept	**Centralised heating system**	**Centralised cooling system**	**Decentralised heating and cooling system**
Reference system	Gas Boiler	Split device Water chiller	Water chiller
Storage system	HWT + ST + Gas PCM + ST + Gas	Water chiller + PCM Water chiller + CWT	PCM surface cooling + water chiller PCM-Ventilation systems
Distribution systems	Radiators Underfloor heating	Surface cooling Fan coil	Air
Additional specifications	Storage material Storage volume Solar collector type + field	Storage material Water-Chiller power Storage volume	Storage material Water-Chiller Power Mass Distribution Storage volume

Table 5: Storage system available combinations.

Please note:
Since the storage function is not related to PCM/TCM material, HWT (Hot Water Tank) and CWT (Cold Water Tank) are not considered innovative storage systems.

Here in Figure 14 an example for the definition of a storage system layout is provided:

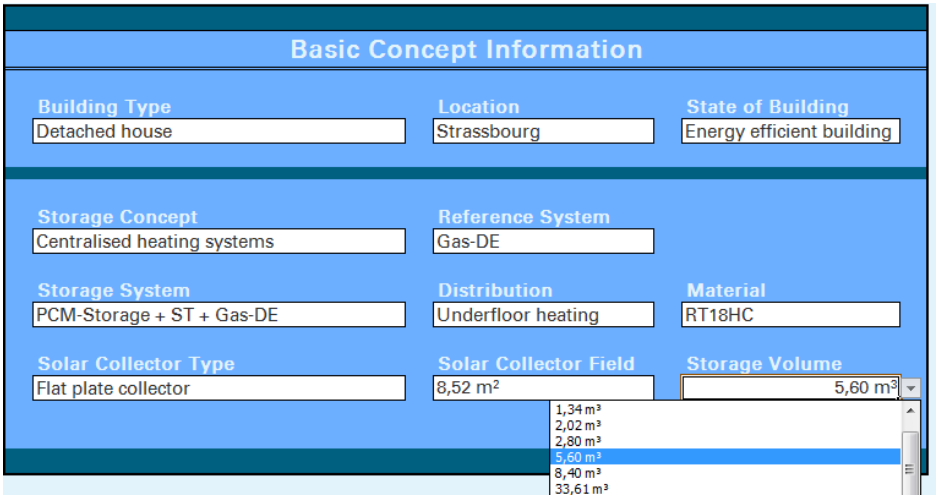


Figure 14: Basic concept Information input screen. Solar collector features and storage volume.

4. For Basic mode, further information about storage and system components cannot be defined (see chapter B-I). The tool will consider a standard system and will provide its information. Furthermore, system specification editing won't be possible: the user can however view components and quantities on the spreadsheet *"Storage Information"* and *"System Information"*. Reference systems are already defined as well.
5. In many cases via the function "Add expert information" the mask provides further specifications, which are intended especially to expert users (see Figure 15).

Please note: Since this is still a Beta-Version and many innovative and reference systems are not yet evaluated, a temporary task bar on the left will notice combination which are available without simulation results (see Figure 15). *If a simulation is still missing, the results are provided only partially*.

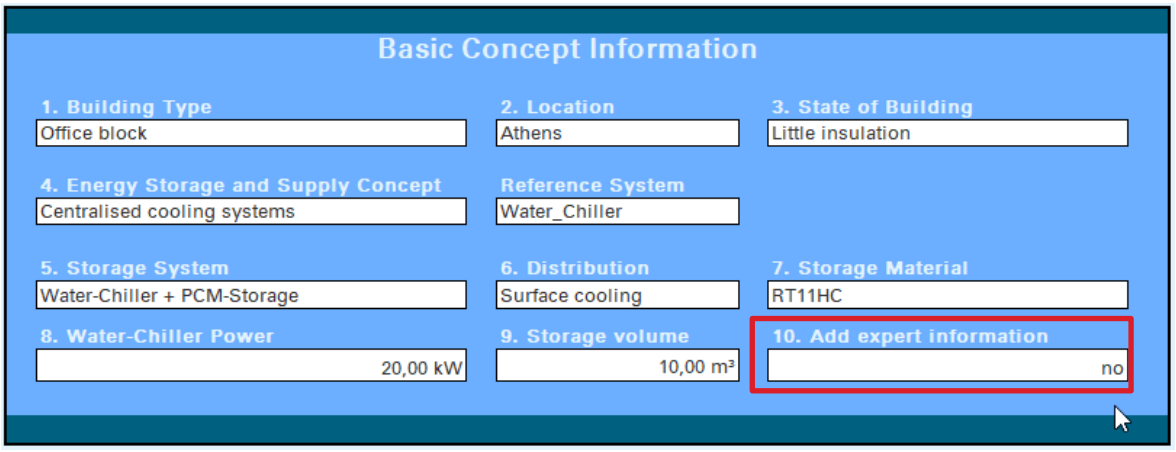


Figure 15: Check availability of selected systems. In the following example the chosen reference system is not available.

III. Results presentation

- For result presentation, click the buttons *"Show results"*/*"Analysis"* or enter directly the spreadsheets:
  - "*LCIA results*" for numerical results or
  - "*Analysis*" for visualization of graphical analysis results.
- The spreadsheet "*Analysis_Basic*" indicates 4 diagrams, here below described in detail.

Please note:
*By clicking the button "**GWP / PEtot**" you may switch environmental result presentation between **Global Warming Potential (GWP)** and **Primary Energy Consumption (PEC**). By clicking the button "Refresh results", results will be updated, when adapting input parameters on the storage system layout within the input mask of spreadsheet "Basic Concept Information"*

***Diagram 1:** The drivers for environmental impacts on component level are identified.*

The storage system layout is divided into three parts:

- **Part 1** (***Storage system***) includes all innovative storage system components that are additionally necessary, e.g. the storage material and containment.
- **Part 2** (***Heating/Cooling system***) summarizes conventional components for heat /cold supply that have to be present due to the specification of the general building supply concept or that complement the innovative storage system e.g. by functioning as back-up units.
- **Part 3** (***Distribution system***) combines conventional components for distribution during heat/cold supply.

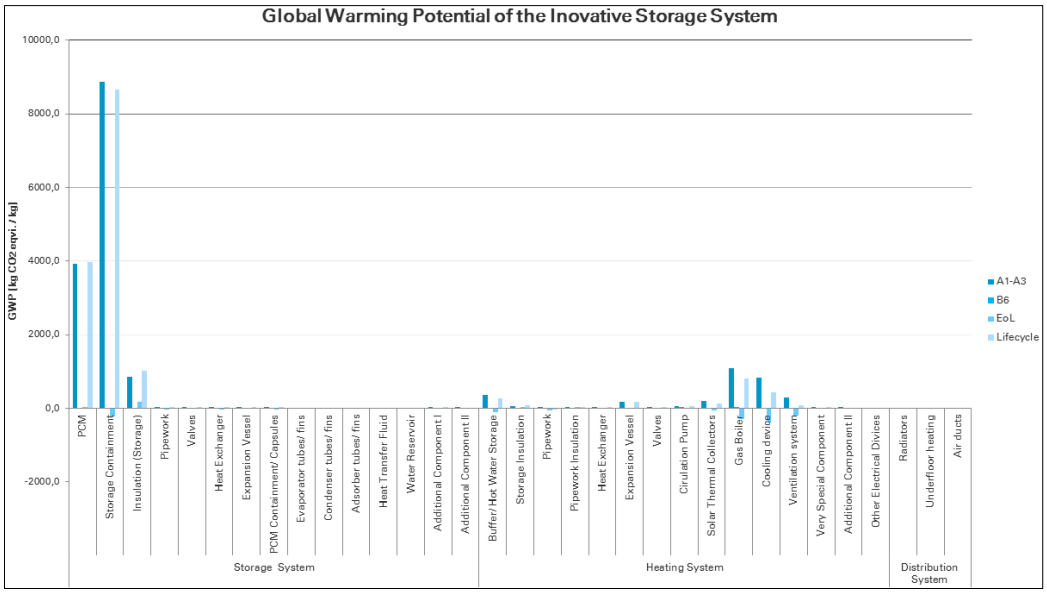


***Figure 16**: Diagram 1 example- Basic mode*

For each component (regardless of its classification into a specific system part), environmental results are displayed, as specified in the introduction, for the following life cycle modules:

- Production phase: A1-A3
- Use phase: B6
- End-of-Life phase: EoL

Positive values indicate hereby a negative effect, resulting in environmental burdens (e.g. production phase) whereas negative values implicate environmental credits (e.g. for material recycling within the End-of-Life phase).

Furthermore, a total *lifecycle* value is provided per each component, aggregating the results from Production, Use and End-of-Life phases.

Diagram 2: *The drivers for environmental impacts on component level are identified and compared to the reference.*

The total lifecycle related environmental impacts are displayed for the innovative storage system and compared to its reference system (without innovative storage). The total values are split down to the shares of each component.

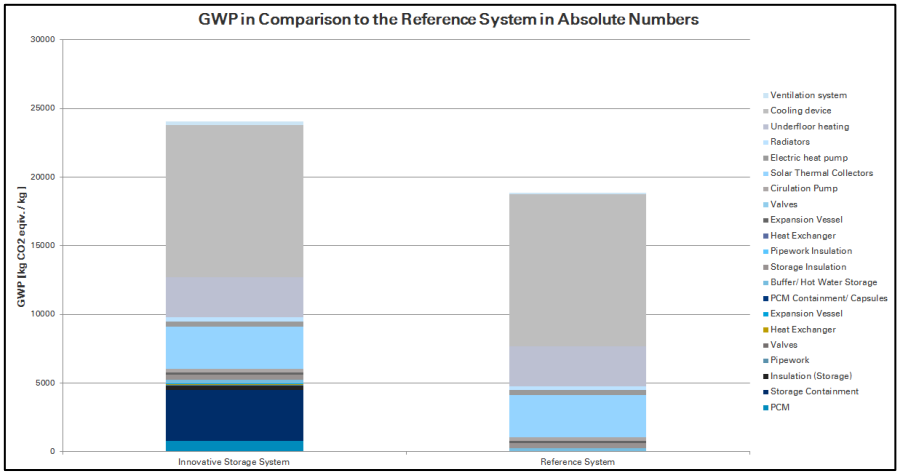


Figure 17: Diagram 2 example

Diagrams 3 and 4: *The drivers for environmental impacts on system part level are identified.*

Relative shares of each system part (storage, heating/cooling, distribution) for the innovative storage system on the total lifecycle related environmental impacts are presented in relation with reference system (percentage values). Furthermore, the total values for each system part are provided.

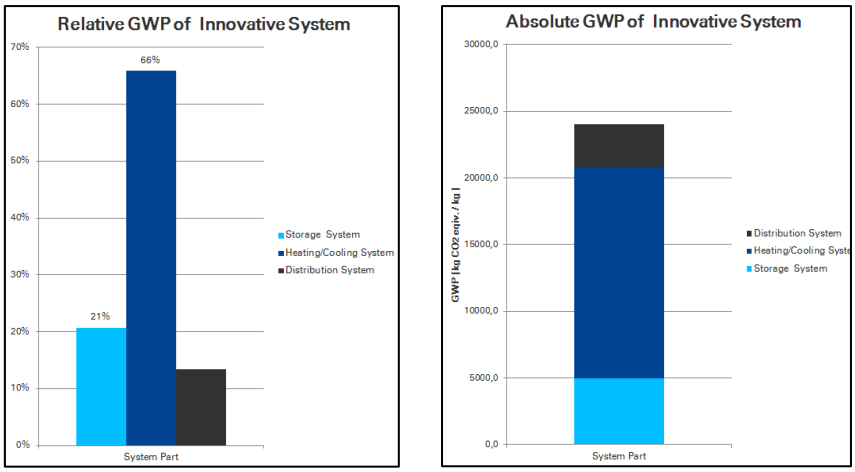


Figure 18: Diagram 3 (on left) and Diagram 4 (on right side)

- The spreadsheet "*LCIA results*" indicates numerical values for the innovative storage system and the graphical presentation within spreadsheet "*Analysis_Basic*".

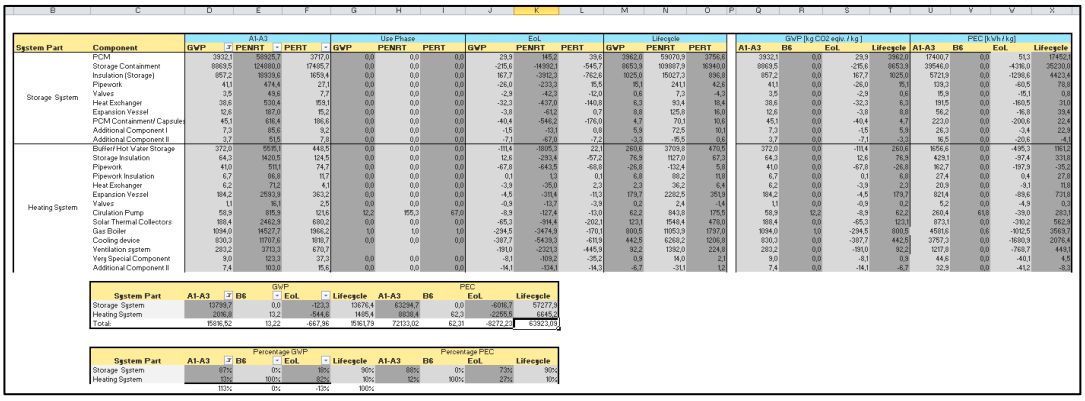


***Figure 19*: Analysis simplified table. Screen from the concerning spreadsheet**

- The spreadsheet "*LCIA results Ref. System*" indicates numerical values for the reference system and its graphical presentation within spreadsheet "*Analysis_Basic*".

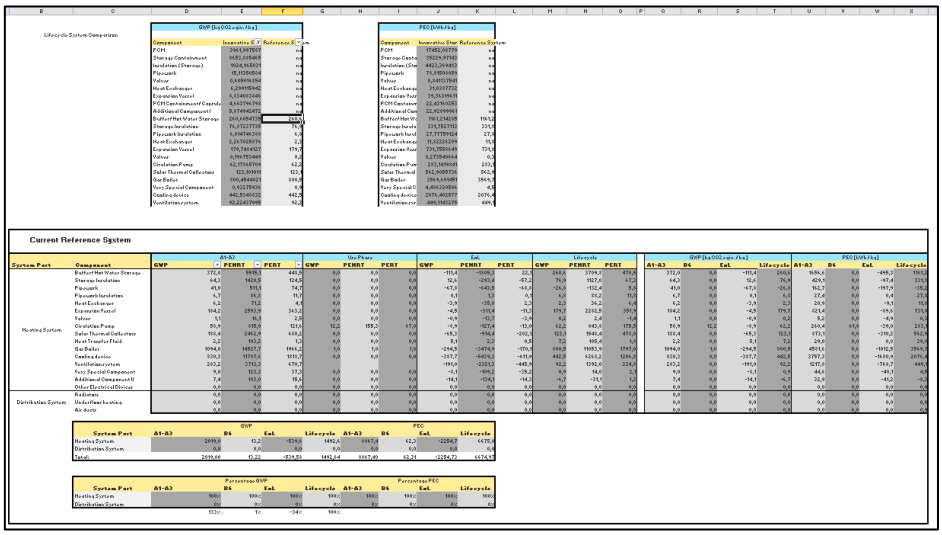


***Figure 20*. LCIA results Ref. System. Spreadsheet screen**

B. Advanced Mode

For customization and analysis of your individual storage system, following options for analysis are provided and indicated in the navigator (see *Figure 11*):

Option 1: Customize individual storage components

Option 2: Customize individual storage concept/system

Option 3: Integration of individual energy demand simulations within a default storage system or your customized storage system

Following Excel spreadsheets are hereby relevant:

- Storage information
- System information
- Use phase information
- Analysis_Advanced
- LCIA results
- LCIA results Ref. System

Before start your analysis, click the button "*Advanced mode*" on "*Basic concept information*" spreadsheet (see Figure 21). All functions are now activated and the user can customize storage system and energy supply concept.Figure 21

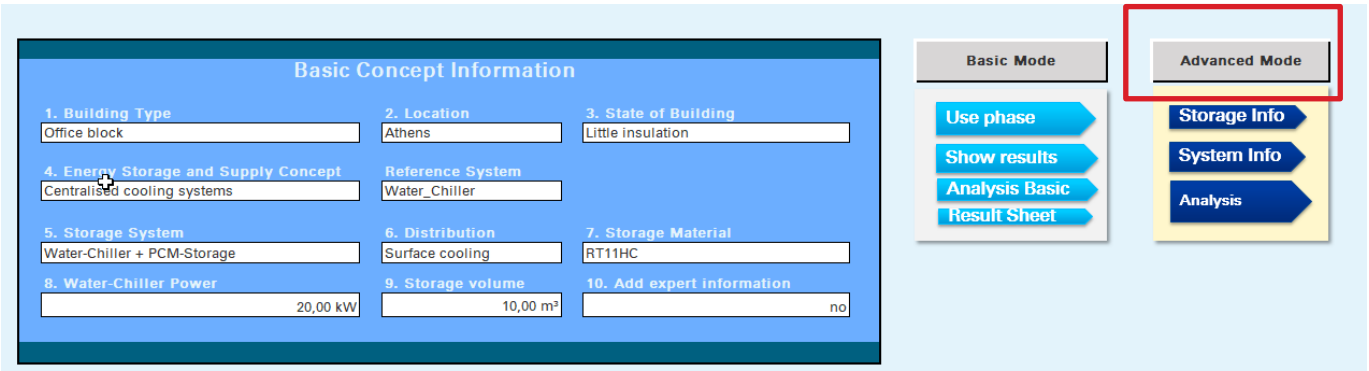


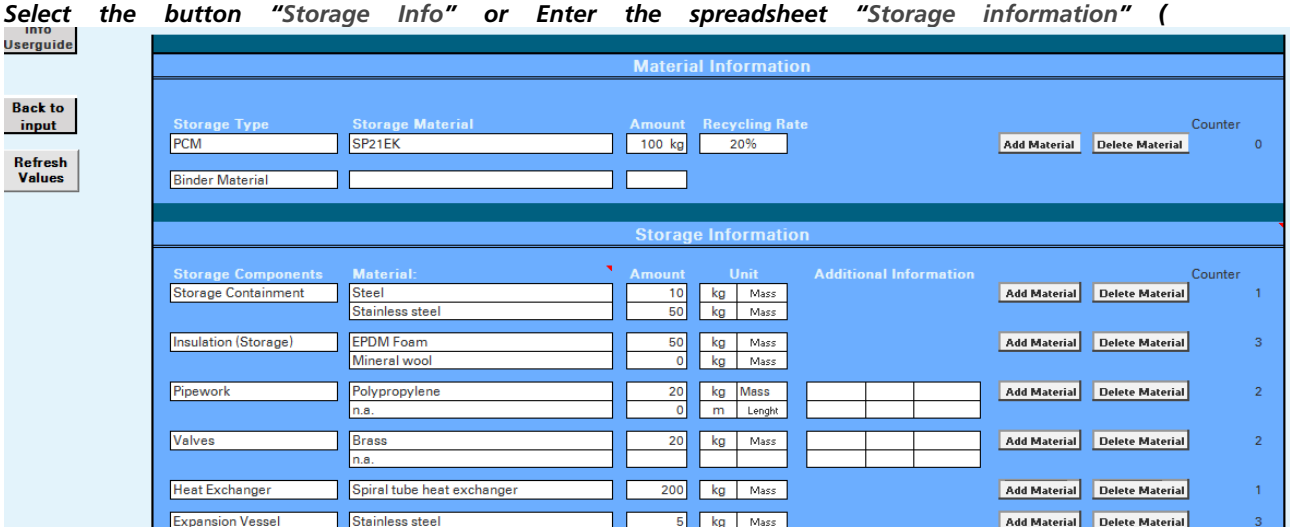
***Figure 21* : A screenshot of the spreadsheet "Basic Concept Information"**

I. Customize and analyze your individual storage components

Performing general settings

1. Define your general building storage concept as well as the reference according to section Basic Mode, chapter II (steps 1. to 3.)

Select the button "Storage Info" or Enter the spreadsheet "Storage information" (



2. Figure 22).

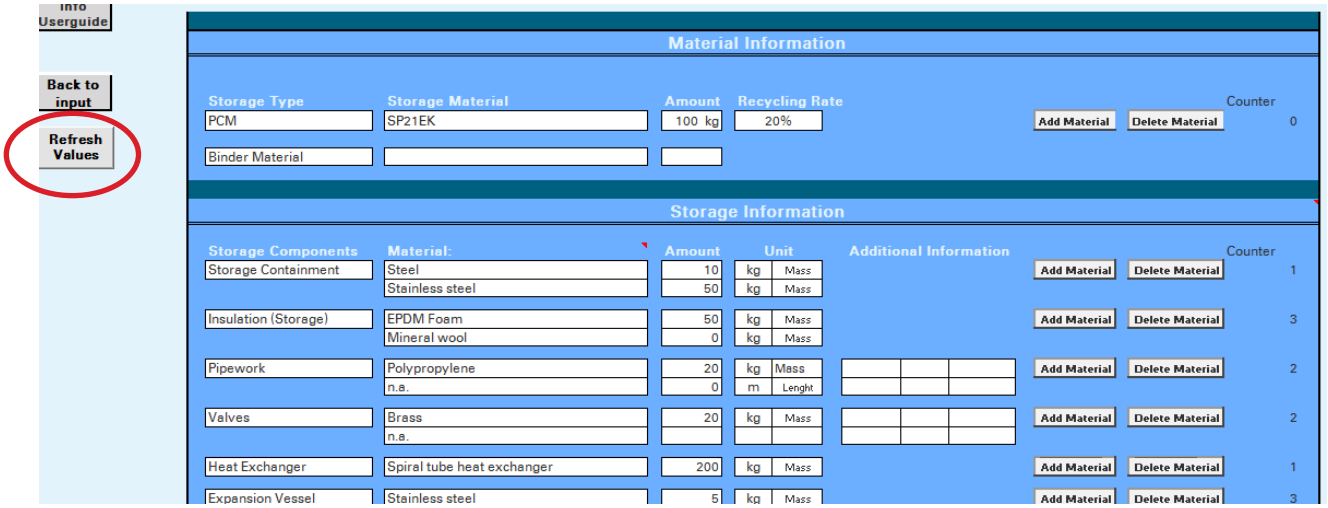


Figure 22: Settings for customization of storage components – Advanced Mode

3. Select the "*Storage type*" (PCM or TCM) and the respective storage material from the default list. Define the specific amount of storage material you want to use (in kg), as well as the recycling rate (in %). If you like to customize a storage material-mix, click on the button "*Add material*" and specify the second one accordingly. Delete via the button "*Delete material*".

   Please note:
   The Tool only offers analysis for the combination of maximum two materials within the same material class. The initial storage material selection within the Basic Mode will be adapted according to your customized settings from above.

4. Specify furthermore the storage containment, meaning the individual storage components, with which you want to operate/combine your storage material/material-mix. For each single storage

component, maximum three materials may be specified. The buttons "*Add Material*" or "*Delete material*" will support you hereby. Please, indicate also material amounts as well as respective units (e.g. mass or volume).

5. For components, that are not active in your storage system layout, please indicate material amounts with "Zero", as it is not possible to delete individual components.

Please note:

Within this Mode the user can upload components and material quantities from standard cases. Click the button "Refresh values" on the link in order to use them. (

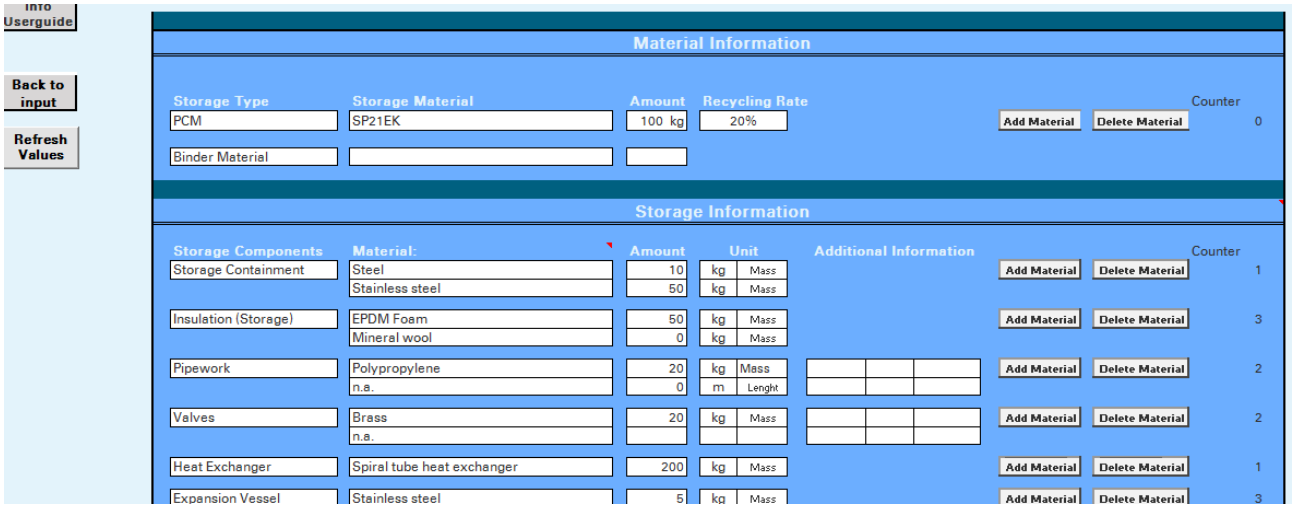


Figure 22).

II. Customize and analyze your energy concept information

Performing general settings

1. Define your general energy concept as well as the reference in according to section Basic Mode, chapter II (steps 1. to 3.)

2. If applicable, customize afterwards your individual component according to section Advanced Mode and chapter I (steps 1. to 4.).

3. From "*Basic Concept information*" click "*System Info*" or enter the spreadsheet "*System information*" (Figure 23).

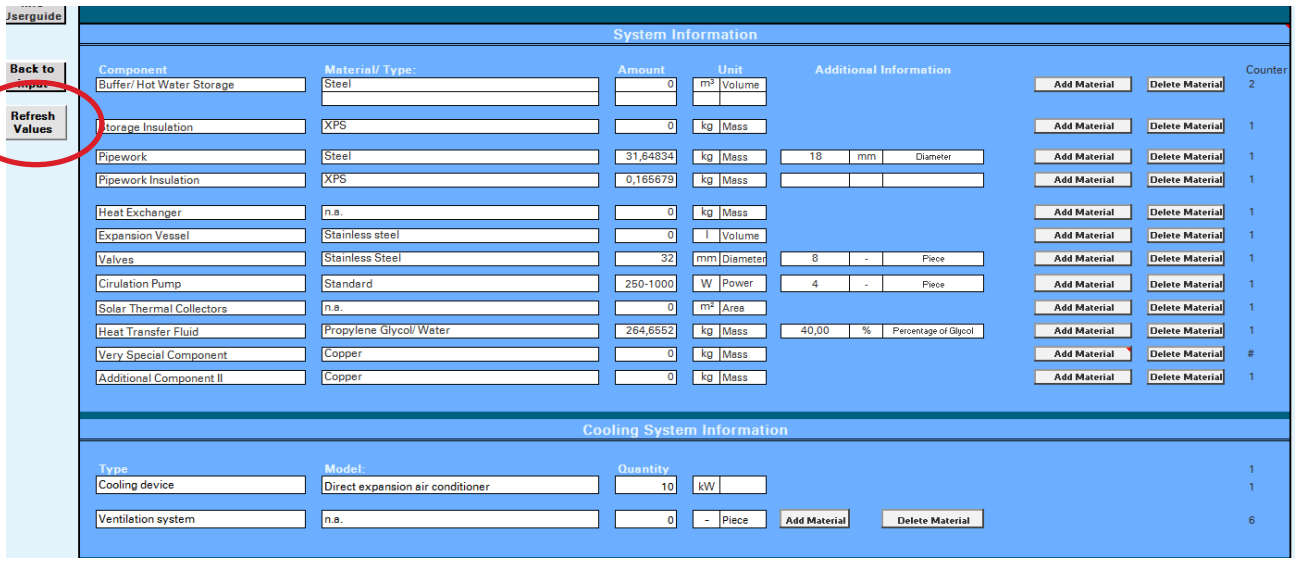


***Figure 23:* Settings for customization of storage system – Advanced Mode**

4. Select additional components for the storage system (*System Information*), the cooling system (*Cooling System Information*) or the distribution system (*Distribution System information*). Furthermore, define the respective material types for each component, as well as specific amounts of material and respective units (e.g. mass or volume). For each single component, maximum three materials may be specified. The buttons "*Add Material*" or "*Delete material*" will support you hereby. Please, indicate also material amounts as well as.).
   As well as in the "*Storage Information*" spreadsheet, please choose the material within the Drop-down List before selecting amount and unit (*mass/volume/length*).

5. For components, that are not active in your system layout, please indicate material amounts with "Zero", as it is not possible to delete individual components.

Please note:
Within this Mode the user can upload components and material quantities from standard cases. Click the button "Refresh values" on the link in order to use them (Figure 24). Reference systems are meanwhile already set up.

III. Integration of individual energy demand simulations into analysis

Performing general settings

1. From "*Basic Concept information*" click "*Use Phase Info*" or enter the spreadsheet "*Use-phase information*".

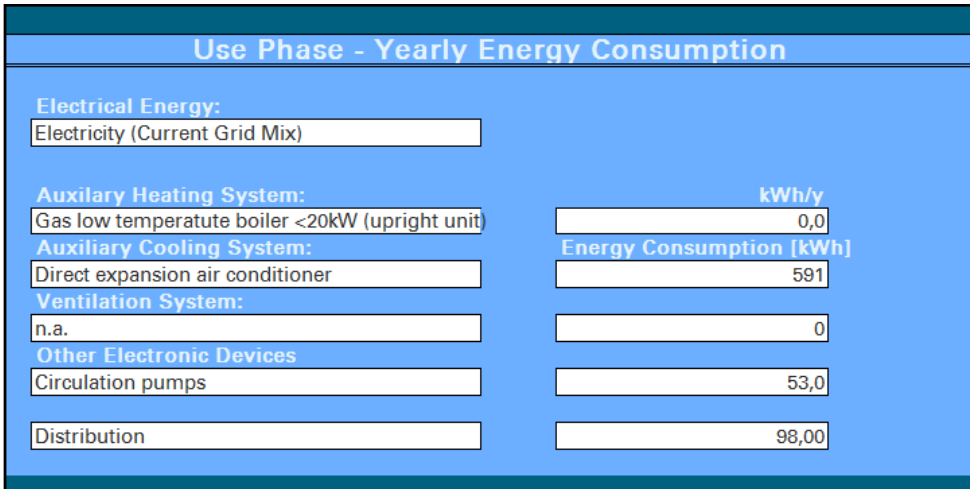


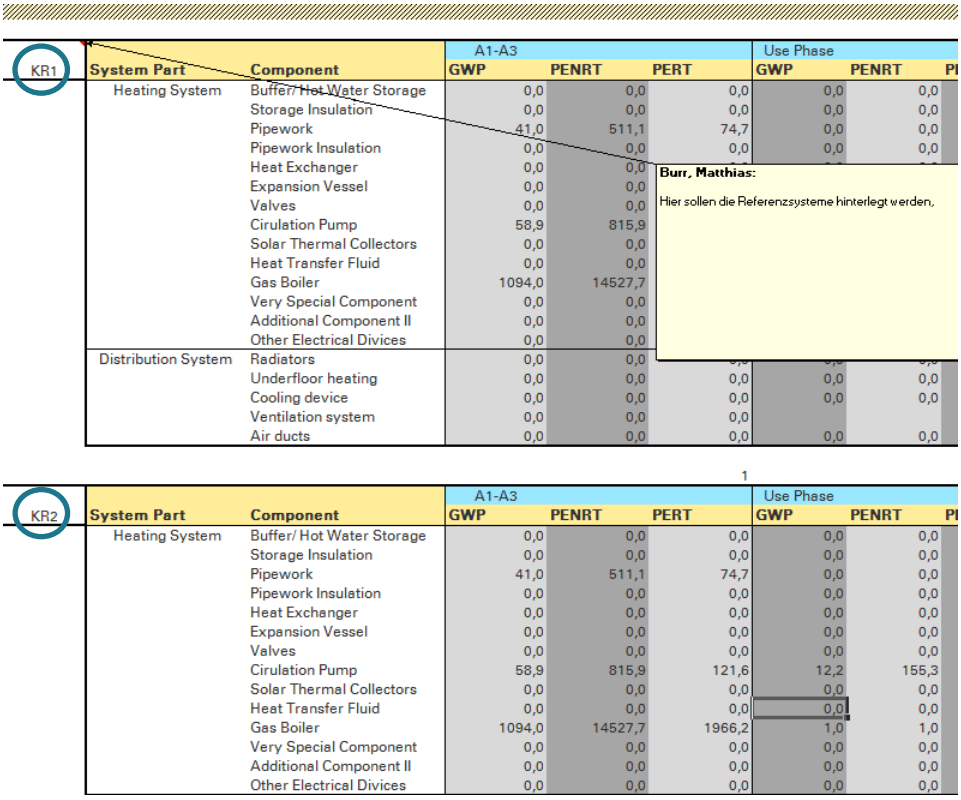
***Figure 25*: Use phase (yearly energy consuption) specification – Advanced Mode**

2. As basis for the energy consumption evaluation, the electrical energy source is already provided: the results are coming from energy simulation and include auxiliary cooling and heating, ventilation systems, circulation pumps. Advance users can freely fill the last box in order to add to the analysis further electronic devices.

IV. Result presentation

By carrying out analyses in **Advanced Mode**, result presentation is available in both "*Basic*" and "*Advanced*" representations.

- *Results*"Spreadsheet shows exhaustive and detailed information about GWP and PEC Impacts due to storage, heating and distribution components only in A1-A3 and EoL stages.
- "*LCIA Results*" provided such environmental impacts of heating and storage components, by adding the use stage.
- "*LCIA Results Ref. System*" provides GWP and PEC impacts of heating and distribution components during the life cycle of the building. In the spreadsheet are given different tables (KR1, KR2, etc.), in which further relevant reference systems can be saved (see *Figure 26*).



KR1

System Part	Component	A1-A3 GWP	A1-A3 PENRT	A1-A3 PERT	Use Phase GWP	Use Phase PENRT	Use Phase PI
Heating System	Buffer/ Hot Water Storage	0,0	0,0	0,0	0,0	0,0	
	Storage Insulation	0,0	0,0	0,0	0,0	0,0	
	Pipework	41,0	511,1	74,7	0,0	0,0	
	Pipework Insulation	0,0	0,0	0,0	0,0	0,0	
	Heat Exchanger	0,0	0,0				
	Expansion Vessel	0,0	0,0				
	Valves	0,0	0,0				
	Cirulation Pump	58,9	815,9				
	Solar Thermal Collectors	0,0	0,0				
	Heat Transfer Fluid	0,0	0,0				
	Gas Boiler	1094,0	14527,7				
	Very Special Component	0,0	0,0				
	Additional Component II	0,0	0,0				
	Other Electrical Divices	0,0	0,0				
Distribution System	Radiators	0,0	0,0				
	Underfloor heating	0,0	0,0	0,0	0,0	0,0	
	Cooling device	0,0	0,0	0,0	0,0	0,0	
	Ventilation system	0,0	0,0	0,0			
	Air ducts	0,0	0,0	0,0	0,0	0,0	

Burr, Matthias:
Hier sollen die Referenzsysteme hinterlegt werden.

1

KR2

System Part	Component	A1-A3 GWP	A1-A3 PENRT	A1-A3 PERT	Use Phase GWP	Use Phase PENRT	Use Phase PI
Heating System	Buffer/ Hot Water Storage	0,0	0,0	0,0	0,0	0,0	
	Storage Insulation	0,0	0,0	0,0	0,0	0,0	
	Pipework	41,0	511,1	74,7	0,0	0,0	
	Pipework Insulation	0,0	0,0	0,0	0,0	0,0	
	Heat Exchanger	0,0	0,0	0,0	0,0	0,0	
	Expansion Vessel	0,0	0,0	0,0	0,0	0,0	
	Valves	0,0	0,0	0,0	0,0	0,0	
	Cirulation Pump	58,9	815,9	121,6	12,2	155,3	
	Solar Thermal Collectors	0,0	0,0	0,0	0,0	0,0	
	Heat Transfer Fluid	0,0	0,0	0,0	0,0	0,0	
	Gas Boiler	1094,0	14527,7	1966,2	1,0	1,0	
	Very Special Component	0,0	0,0	0,0	0,0	0,0	
	Additional Component II	0,0	0,0	0,0	0,0	0,0	
	Other Electrical Divices	0,0	0,0	0,0	0,0	0,0	

Figure 26: LCIA Results Ref. System criteria definition – Advanced Mode

- By click the button "*Analysis Basic*" or enter directly the spreadsheet "*Analysis_Basic*", the visualization is the one already described in the previous section "Basic Mode" (chapter A). Please take care to refresh the results via the "*Refresh results*" button.

- An exhaustive result presentation may be also entered within the button "*Analysis Advanced*" or the spreadsheet "*Analysis_Advanced*". Within the spreadsheet a Pivot table with numerical results and a diagram with graphical results are presented. For updated result presentation, please update first the Pivot table by entering the Microsoft-Excel menu "*Data*" and click the button "*Refresh data*".

  Please note:
  Results presented within the spreadsheet "Analysis_Advanced" only refer to your individual customized storage system with regard to constructive aspects (see

Introduction*). Information or results on the reference building/system and the use phase are cut off.*

Within "*Analysis_Advanced*" spreadsheet the ***Pivot Table*** indicates numerical results whereas the Pivot diagram presents the results in a graphical manner (Figure 27).

	Production (A1-A3)			End of Life		
Description	**GWP_Pr**	**PENRT_Pr**	**PERT_Pr**	**Summe von GWP2**	**Summe von PENRT2**	**Summe von PERT2**
Distribution System	**3935,447643**	**16769,03285**	**2099,400474**	**-718,9961265**	**-3977,210527**	**-504,6430911**
Air ducts	0	0	0	0	0	0
Radiators	524,3214634	1999,567057	58,90488919	-216,2084152	-539,0971992	35,62313925
Underfloor heating	3411,126179	14769,4658	2040,495585	-502,7877113	-3438,113327	-540,2662304
Heating/Cooling System	**27342,44143**	**114917,1698**	**18826,67331**	**-11890,79017**	**-47275,31882**	**-5827,55603**
Additional Component II	0	0	0	0	0	0
Buffer/ Hot Water Storage	372,0284632	1531,980007	124,5715225	-111,4229898	-501,4727714	6,135527194
Cirulation Pump	94,18425375	362,6112359	54,02860808	-14,25243175	-56,63675363	-5,775999413
Cooling device	20756,39523	81302,44888	12629,55444	-9693,023151	-37772,96152	-4248,977374
Expansion Vessel	184,2264673	720,5171192	100,8865688	-4,478054619	-86,49937931	-3,148443746
Heat Exchanger	6,167928372	19,76812043	1,129476017	-3,900902496	-9,721240947	0,645906592
Heat Transfer Fluid	3,793264323	20,90326492	1,51631161	0,000886257	-0,001324215	0,000287195
Pipework	40,99930034	141,9782899	20,74075144	-67,81322885	-178,7561395	-19,1239647
Pipework Insulation	6,7158769	24,11987247	3,249344303	0,098869489	0,368851703	0,039522756
Solar Thermal Collectors	4710,281678	17103,24562	4723,320462	-1632,756403	-6350,289376	-1403,637369
Storage Insulation	335,793845	1205,993624	162,4672151	4,943474427	18,44258514	1,976137792
Valves	28,22861843	112,0149895	17,29066556	-23,30978221	-95,42538194	-27,04175654
Ventilation system	283,1869065	1031,470735	186,3085595	-190,9625266	-644,805762	-123,8592048
Very Special Component	0	0	0	0	0	0
Electric heat pump	520,4395939	11340,11803	801,6093889	-153,9139306	-1597,560606	-4,789299462
Total	**31277,88907**	**131686,2027**	**20926,07379**	**-12609,7863**	**-51252,52934**	**-6332,199121**

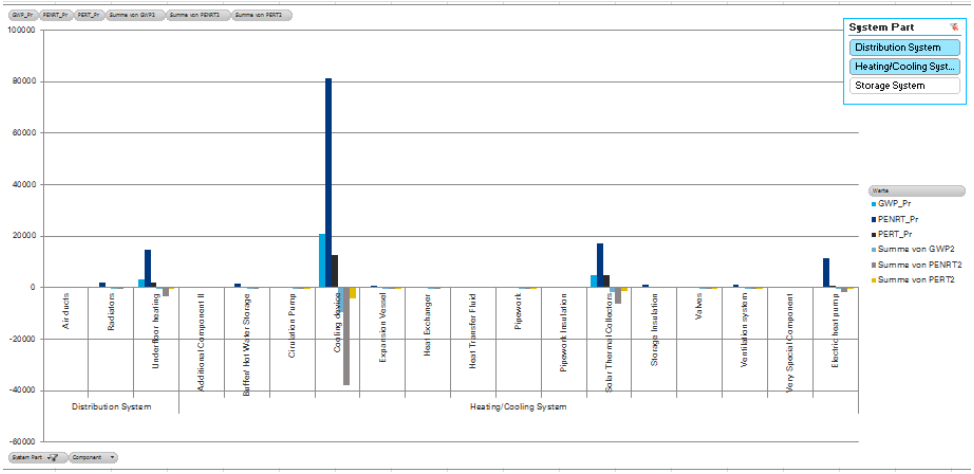


***Figure 27:** Result presentation – Advanced Mode*

- For each component of the storage, the heating/cooling and the distribution system, environmental results are displayed in detail for the following life cycle modules:
  - Production phase: A1-A3
  - End-of-Life phase: EoL

  Positive values indicate hereby a negative effect, resulting in environmental burdens (e.g. production phase) whereas negative values implicate environmental credits (e.g. for material recycling within the End-of-Life phase).

- Furthermore, a lifecycle value is provided per each component, by aggregating the results from Production and End-of-Life phase.
- You may customize result presentation via the *filter functions*, either directly within the Pivot table or within the Pivot diagram (highlighted in black within Figure 28). Hereby, you have the option to display either single component or single system parts and to filter in the way that it is useful for your specific analysis application.

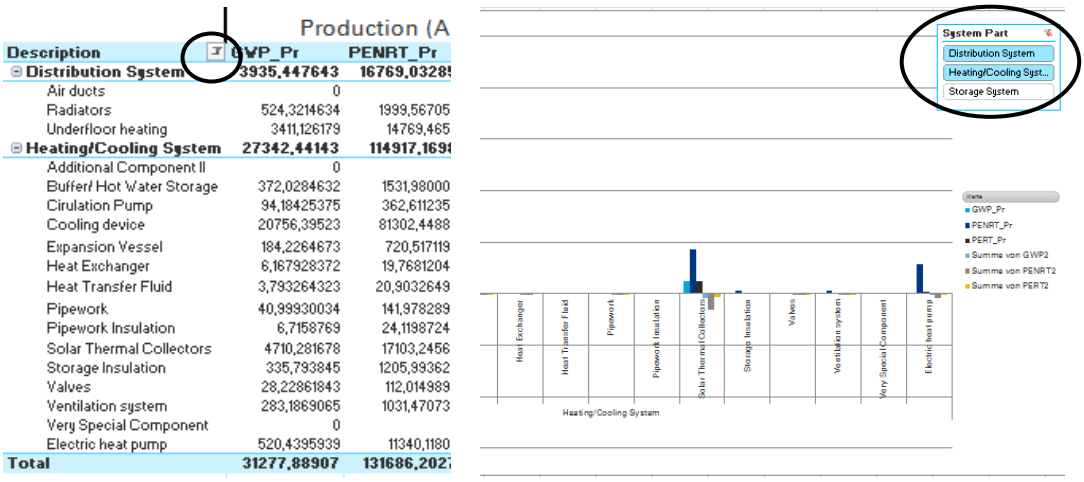


***Figure 28:** Filter functions within result presentation – Advanced Mode*

- In such **Advanced Mode** representation, results are provided as well for the selected reference system.
  The user may customize result presentation through the *filter functions*: the first one (highlighted in black) can select the reference system, in which KR0 is the one related to the selected system concept; the second one (highlighted in blue) gives the option to display either single component or single system parts (see Figure 29).

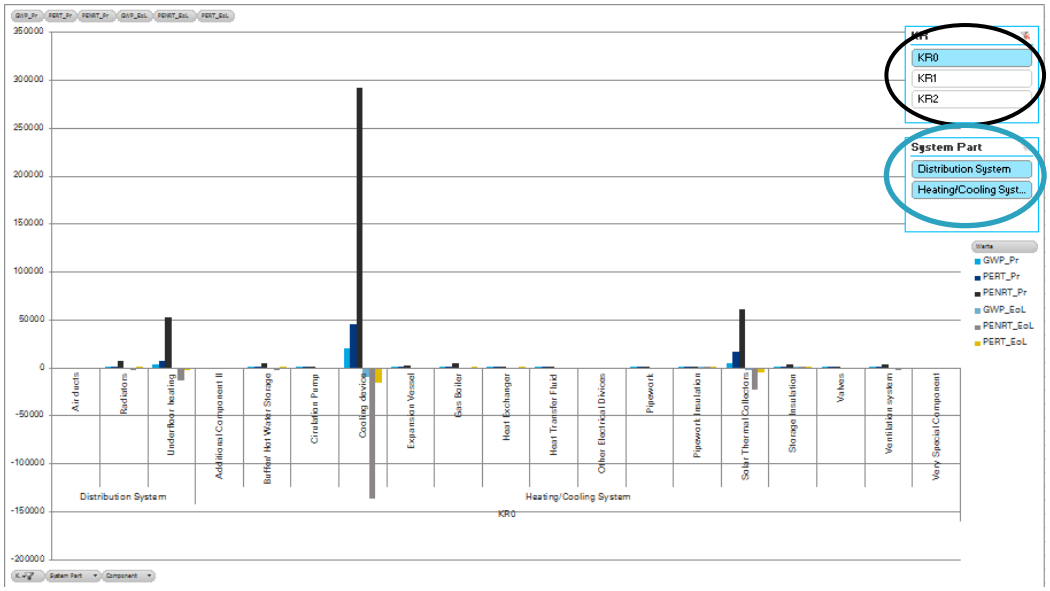


***Figure 29**: Filter function with result presentation of reference system – Advanced Mode*

Results sheet – Basic

By selecting the spreadsheet "*Result sheet-Basic*", a short overview on results is provided.

Evironmental Impact: Evaluation on System-Level

	Innovative Storage System	*Reference System*
Building Type:	Office block	Office block
Location:	Athens	Athens
State of Building:	Little insulation	Little insulation
Storage Concept:	Centralised cooling systems	Centralised cooling systems
Storage System:	Water-Chiller + PCM-Storage	Water_Chiller
Storage Material:	RT18HC PCM	Cold water tank
Energy Density [kWh/kg]:	0,2706	0,897
Temperature range:	(Min. Temp ; Max. Temp) = 21; 40 [°C]	Density: 2700[kg/m³]

***Figure 30*: Main building specifications – Results sheet screenshot**

- The first part of this sheet (Diagrams 1-2) is focused on the whole system level: on the top (see Figure 30) the main specification of building and storage system are reported. Below 4 diagrams help users for a final evaluation of the building and supply systems impacts.
- The last part (Diagrams n. 3-4-5) shows the results on the component level of the selected storage system.
- Additional information about total GWP, system features, SEER and utilization degree are provided in the boxes next to the diagrams

Diagram 1 (Page 1)

After evaluating GWP and PEC, they are shown in percentage of Lifecycle impacts due to reference system. This leads to a comparative analysis between the 2 different systems (value range from "*LCIA results*" and "*LCIA Ref. System results*" spreadsheet).

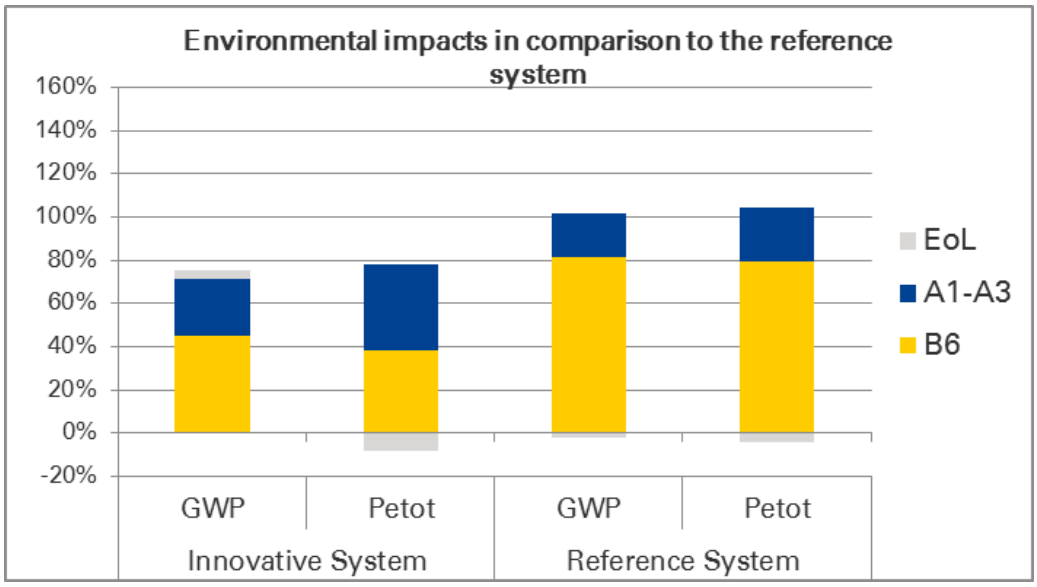


***Figure 31*: Diagram 1 example**

Diagram 2 (Page 1)

By focusing on innovative storage system, a more detailed representation of impacts is entered. Here are reported as quantities in relationship with the total impact during lifecycle (value range from "*LCIA results*" spreadsheet).

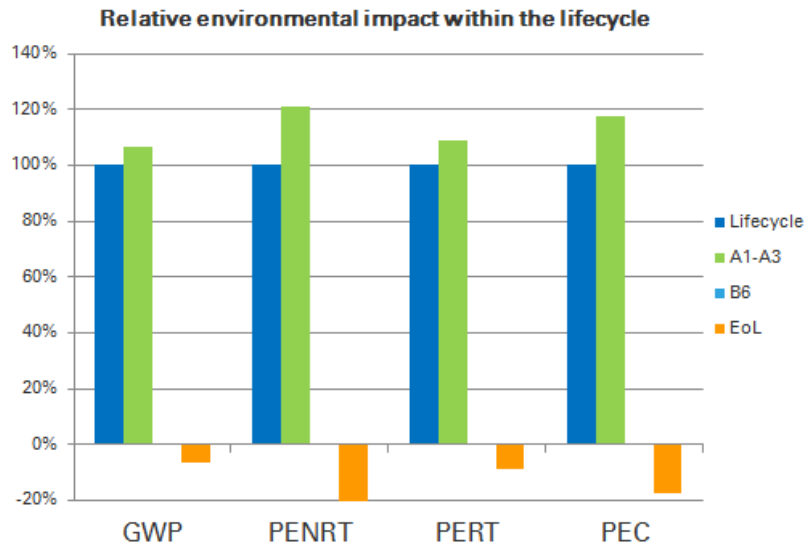


***Figure 32*: Diagram 2 example**

Diagram 3 (Page 2)

With reference on GWP, the diagram shows the distribution of the environmental impact on Storage, Heating, and Distribution systems; if considered, the LCIA analysis reports the impacts due to the using phase (value range from "*LCIA results*" spreadsheet).

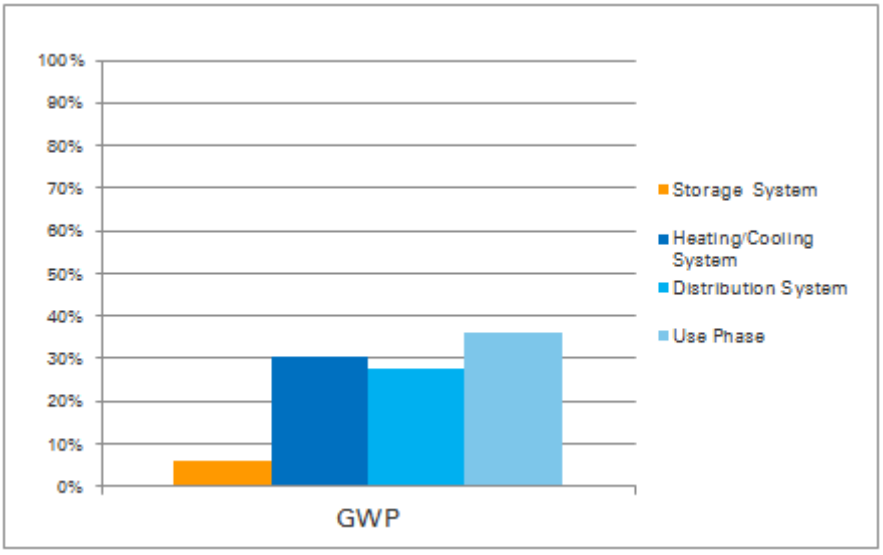


***Figure 33*: Diagram 3 example**

Diagrams 4-5 (Page 2)

The last 2 graphs show the distributions, respectively, of storage system components and the ones not belonging to this (peripheral compositions).

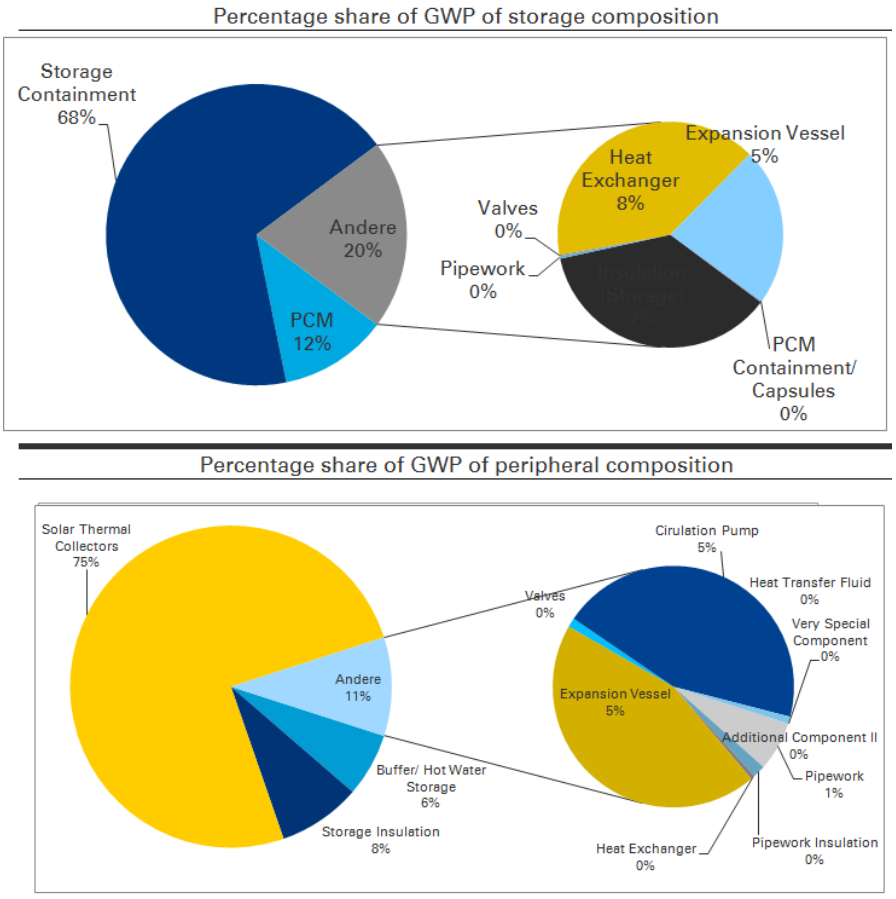


Figure 34

Pages 3 – 4 are similar to the second one: with regard to PERT and PENRT, the analyses are provided following the same approach.

Please note at page n. 5 the Button "*Print Report*" (Figure 35), which opens a print preview. A default layout is already provided, but the user can modify this through the printer settings (Figure 36).

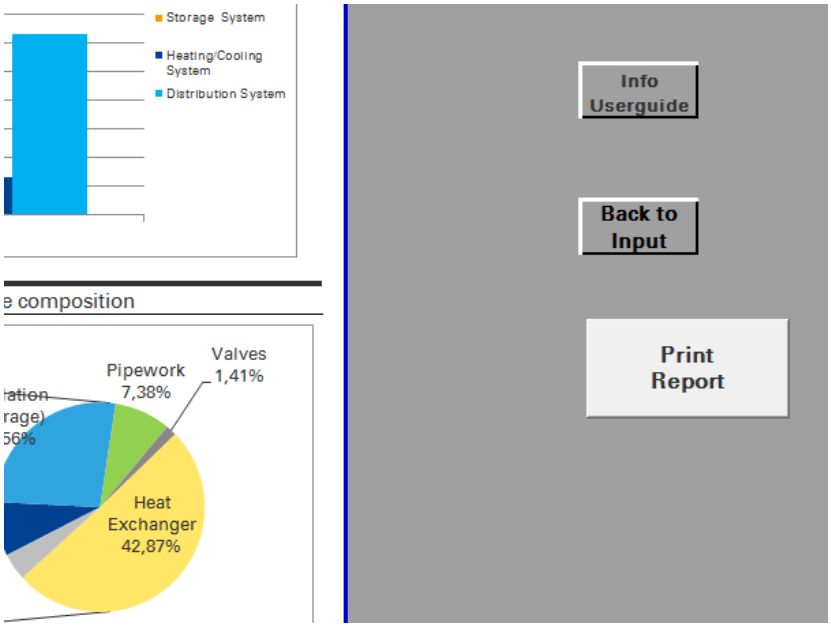


***Figure 35**: Print Report Button*

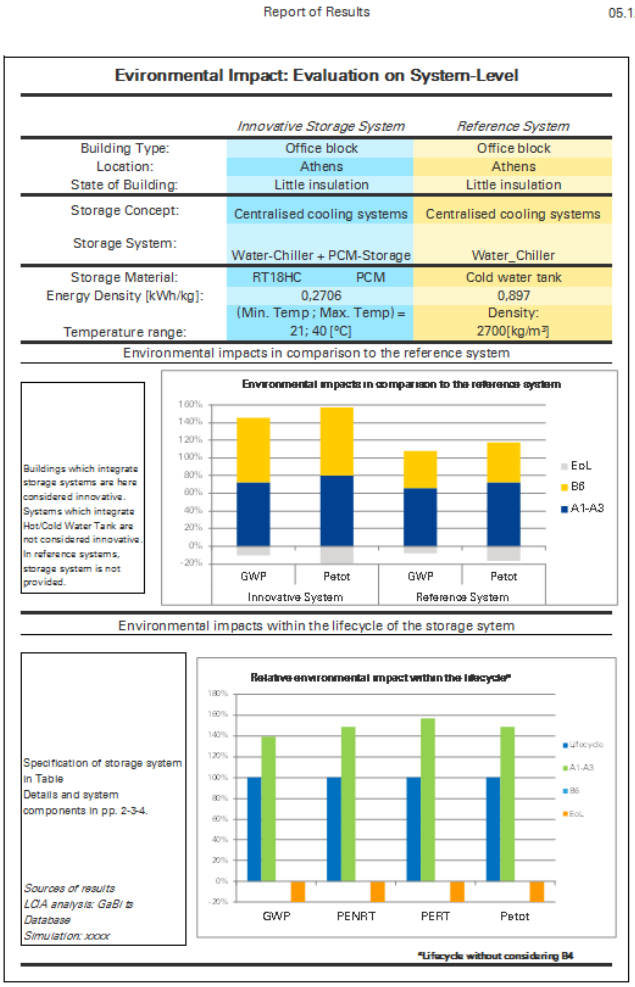


***Figure 36**: Print preview*