Design tool for thermal energy storage in buildings

Dr. Nikolaos Stathopoulos - NCSR ‘Demokritos’, Greece

Asst. Prof. Pär Johansson - Chalmers University of Technology, Sweden

Prof. Angela Sasic Kalagasidis - Chalmers University of Technology, Sweden

12th International Scientific Conference on Energy and Climate Change

NKUA – KEPA, 9-11 October 2019, Athens, Greece

Context & Problem statement

Building sector

1/3 of final energy use, 1/3 of global GHG emissions

Need for efficient energy systems and Renewable Energy Sources (RES)

Thermal Energy Storage

- Overcome variability and intermittence of RES
- Allows saving of excess thermal energy
- Shift consumption to off-peak period / Restitution of energy at a later period
- Contribute to energy supply security
- Improvement of thermal comfort

Context & Problem statement

Latent heat storage with Phase Change Materials (PCMs)

- Occurs during the phase change of a heat storage material
  - Much higher storage capacity
  - Smaller volume
  - Narrower temperature operating range
- Building sector applications: passive (walls) or active (HVAC systems)

Limitations & barriers

- Limited integration of TES-PCM in building sector
- PCM technology has not yet reached a wide commercialization stage
- Coupling of TES-PCM with other systems
- Overall performance and expected benefits

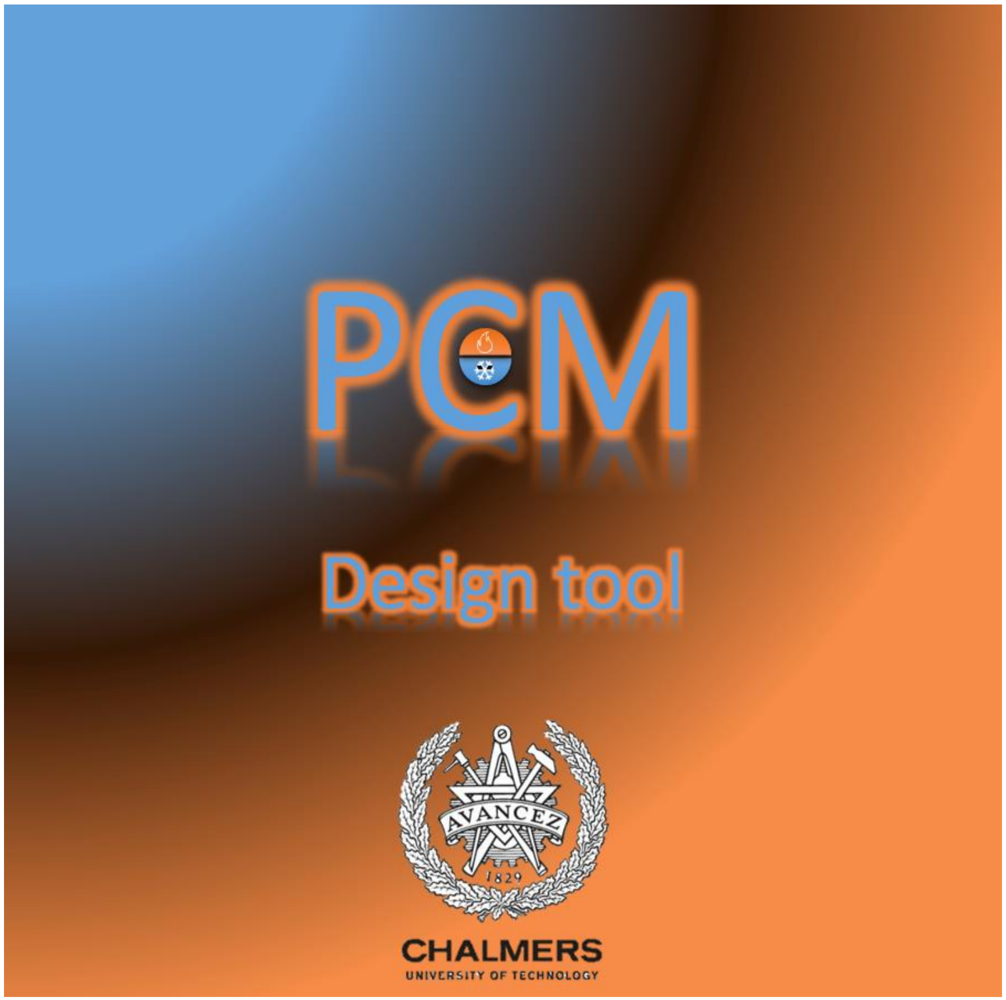
Context & Problem statement

Existing databases and tools

No.	Name	Database/software tool	Access
1	MatWeb	Online database	Free
2	MATERIA	Online database	Free
3	MPDB	Material property database	Paid/Demo
4	ThermoLit	NIST online database	Free
5	IDEMAT	Material selection online database and software	Free
6	CES Selector	Material selection software	Paid/Demo
7	GRANTA MI	Material database management software	Paid/Demo
8	Thermo-Calc	Thermodynamic properties calculation software	Paid/Demo
9	PCMexpress	Simulation tool	Free
10	Worksheet database	Computational Tool	Free

Nazir et al., 2019: *Recent developments in phase change materials for energy storage applications: A review*. International Journal of Heat and Mass Transfer.

Development of TES-PCM design tool



Programming environment

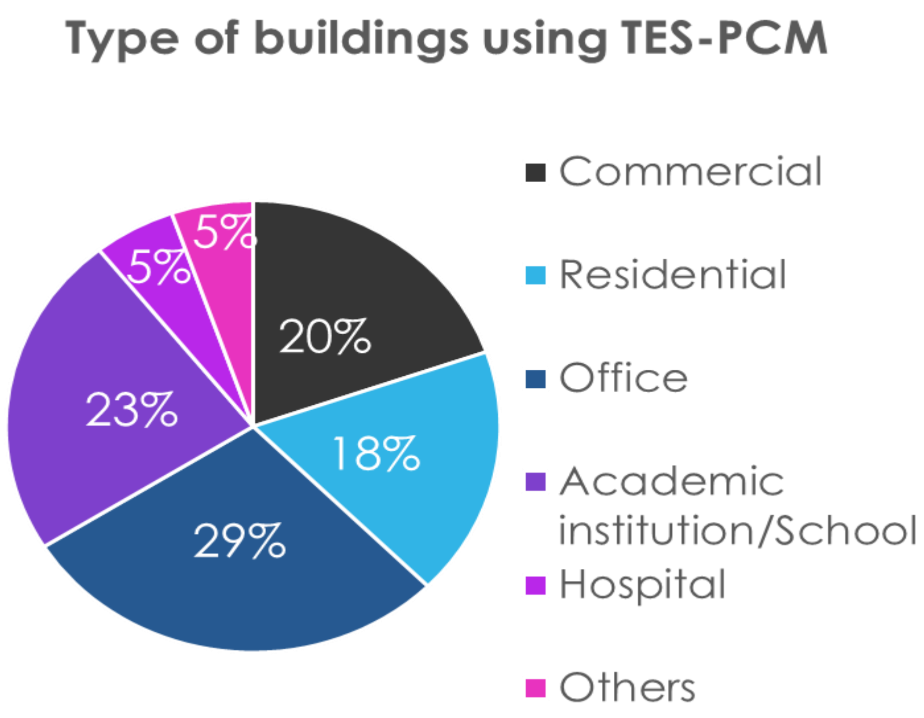
MATLAB
- Graphical User Interfaces (GUI)
- Runtime

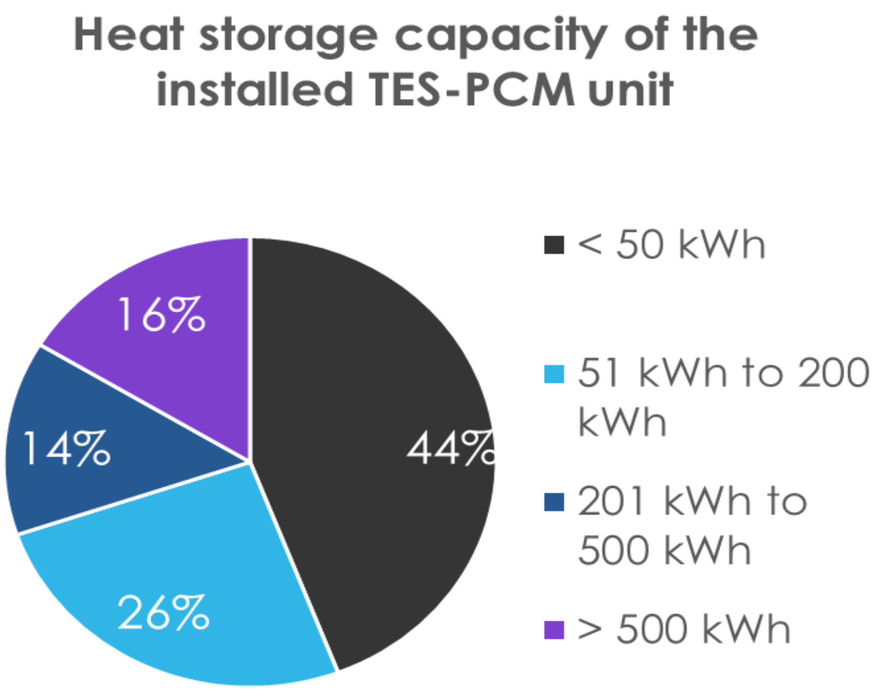
Use of previously developed numerical PCM model

Open to further expansions

Survey among potential users

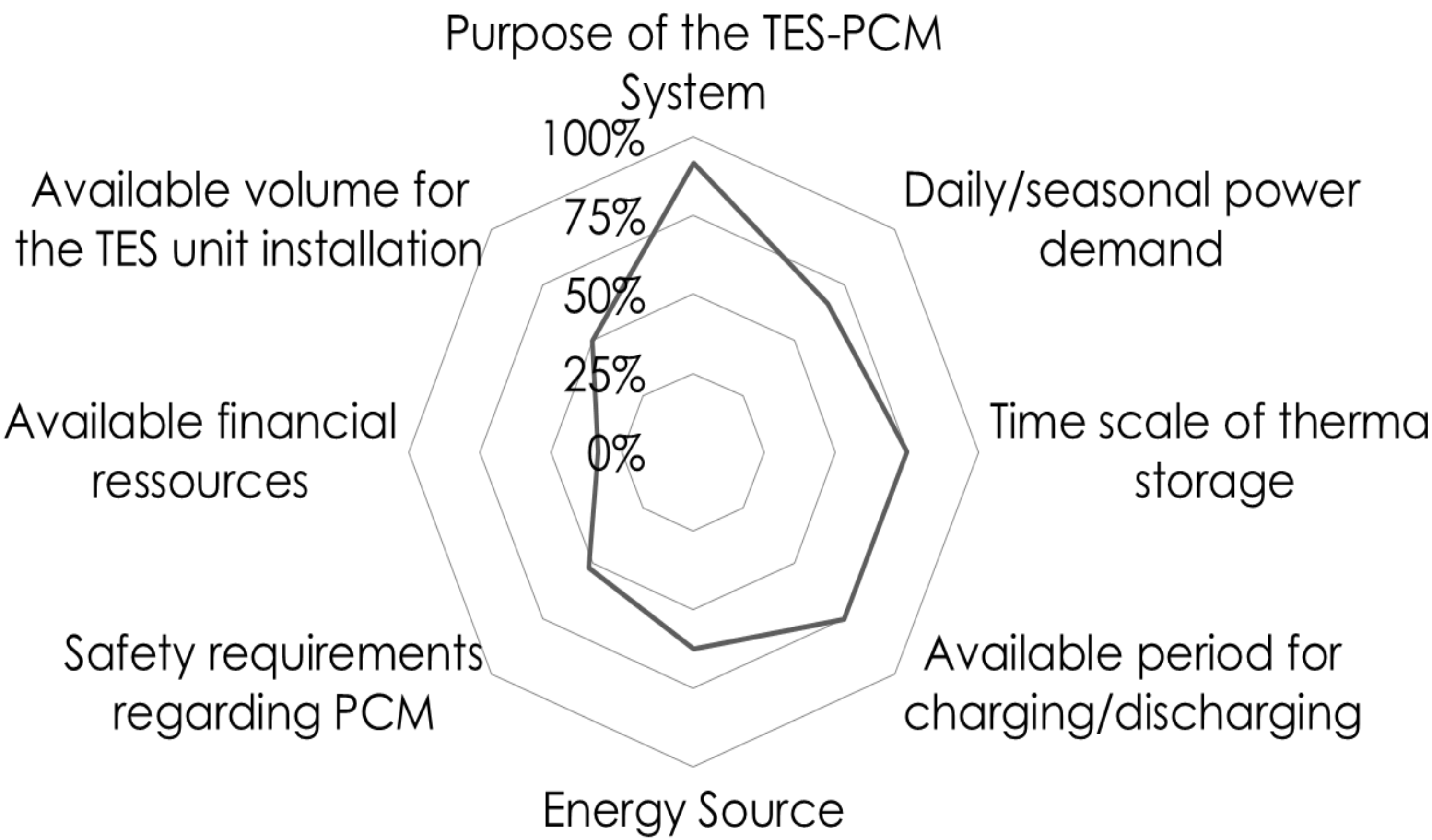
- Why: needs and available information of potential users
- 48 participants: energy consultants, real estate owners, PCM producers, technical managers, researchers



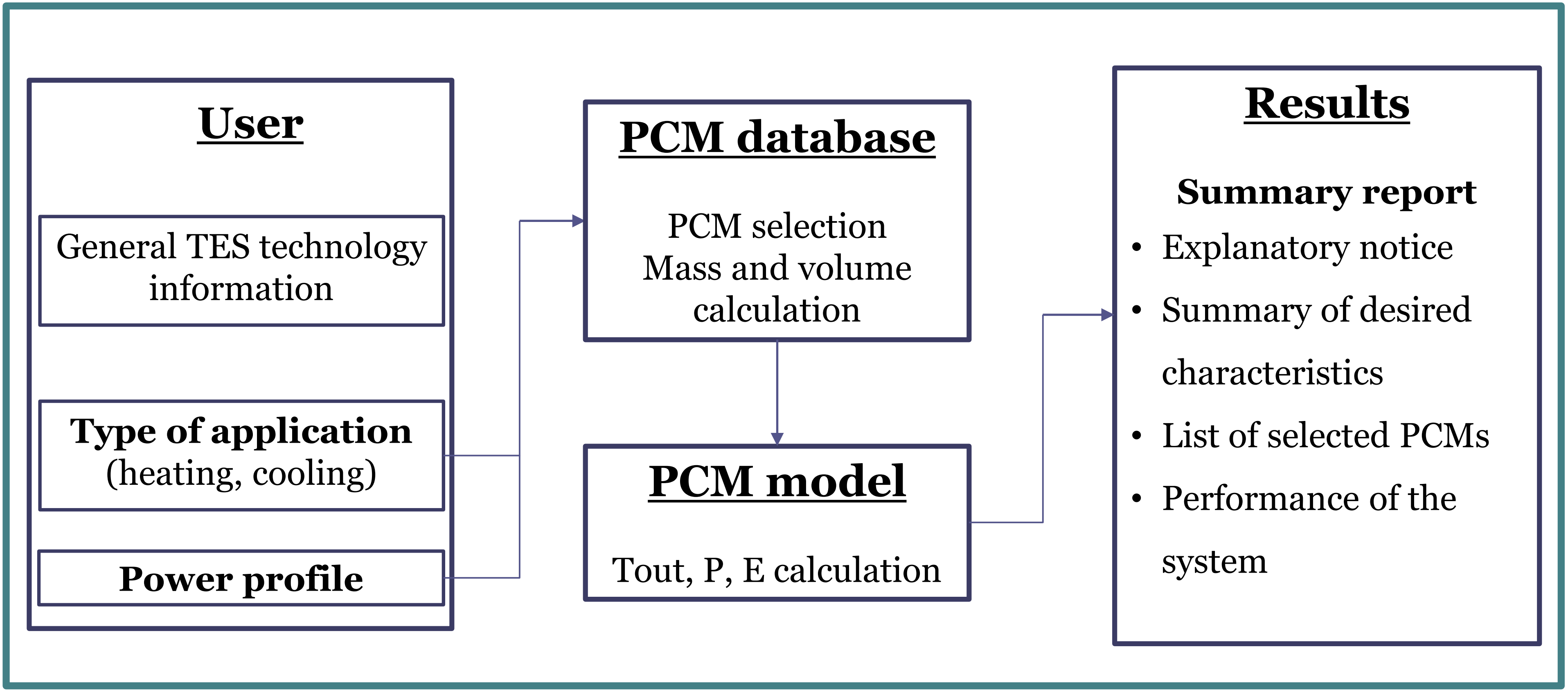


Survey among potential users

Available information during design process of TES-PCM



Structure of the TES-PCM design tool



User component

HOME

PCM

Summary

1. Why Thermal Energy Storage?

2. What is a PCM?

3. How does this work?

4. Give me an example

5. Why use PCM?

6. About us

Why Thermal Energy Storage?

Bridging the gap between the time of demand, and the present availability of energy, calls for effective methods of energy storage. As heating and cooling account for a significant amount of the total energy consumption, thermal energy storage (TES) techniques have proven to be cost effective. Furthermore, the implementation of TES systems works favorably with the upcoming concept of decentralized energy generation in both urban and rural areas.

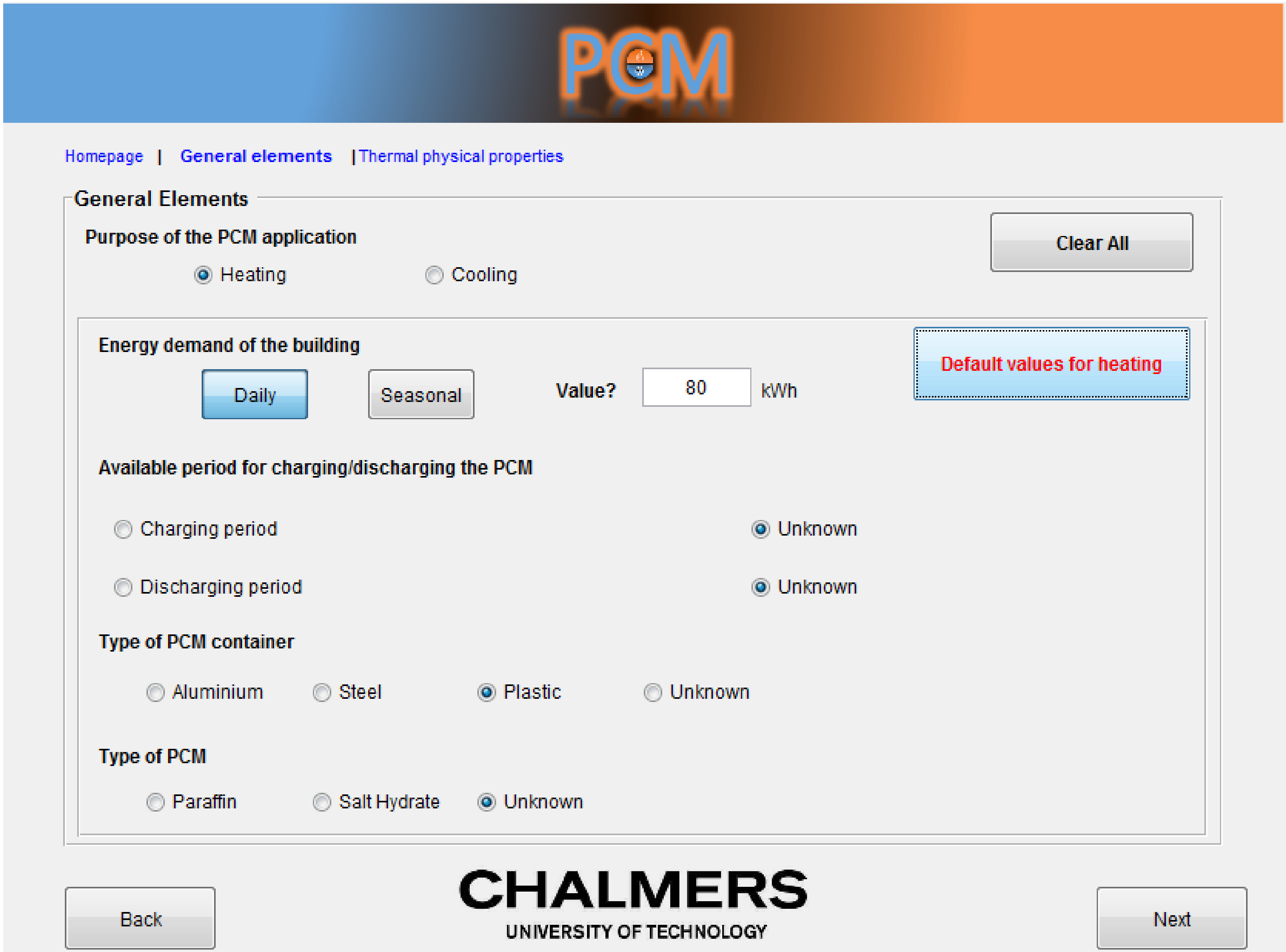
TES technology allows energy to be stored during periods of low demand and to provide it when the demand is high. In view of this, TES is considered as being one of the most promising technologies to reduce peak demand or shift energy loads from high consumption periods (peak hours) to low consumption periods (off-peak hours). This technology is well adapted for use with intermittent renewable energy sources because it stores energy when it is at its most abundant and distributes it in time of need.

I want to read a more detailed document in PDF form including information on:
- Thermal Energy Storage (principle, methods and comparison)
- Phase Change Material (fundamentals, advantages, applications, materials, containment and design considerations).

CHALMERS
UNIVERSITY OF TECHNOLOGY

Back

User component



PCM database

- ❑ Commercially available PCMs (major worldwide PCM producers)
- ❑ Cooling purposes: 0°C and 20°C, Heating purposes: 20°C and 60°C
- ❑ Necessary information: heat capacity curves (solid, liquid, phase change), density (solid, liquid), thermal conductivity (solid, liquid) and volume expansion.

User Input + Database = Selection of suitable PCM(s)

Selection of PCM(s) based on the input from the user :

- Temperature range of the phase transition
- Purpose of the application (heating or cooling)
- Type of PCM
- Charging and discharging temperature of the HTF

Calculation of PCM mass and volume of the system

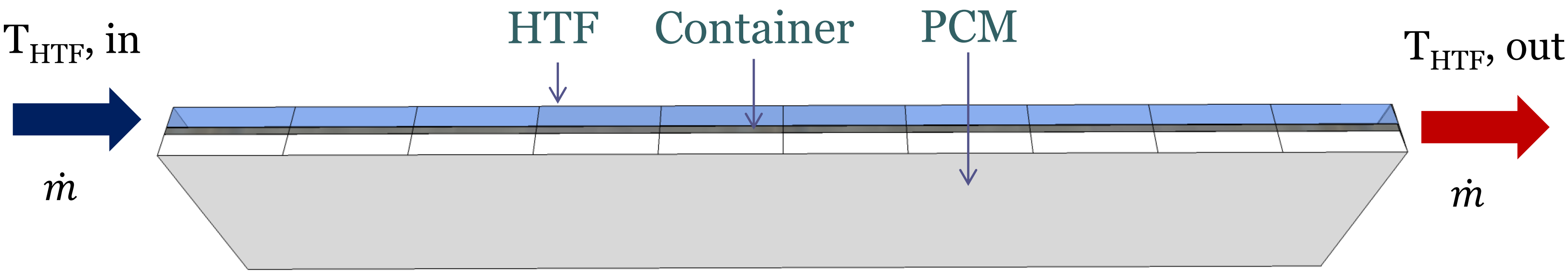
Needed material mass and application volume is calculated for every suitable PCM.

PCM database

Name	Phase Change Temperature °C	Type	Purpose	Latent Heat Fusion kJ/kg	Specific Heat kJ/kg.K
RT 5	6	Paraffin	Cooling	180	2
RT 5	6	Paraffin	Cooling	180	2
RT 10	10	Paraffin	Cooling	160	2
RT 10	10	Paraffin	Cooling	160	2
RT 15	14	Paraffin	Cooling	155	2
RT 15	14	Paraffin	Cooling	155	2
RT 50	49	Paraffin	Heating	160	2
RT 50	49	Paraffin	Heating	160	2
RT 35	33	Paraffin	Heating	160	2
RT 35	33	Paraffin	Heating	160	2
SP 5	5	Salt Hydrate	Cooling	170	2
SP 5	5	Salt Hydrate	Cooling	170	2
SP 31	32	Salt Hydrate	Cooling	210	2
SP 31	32	Salt Hydrate	Heating	210	2
SP 50	50	Salt Hydrate	Cooling	220	2
SP 50	50	Salt Hydrate	Heating	220	2

PCM numerical model

- Developed in LGCB laboratory, ENTPE, France
- Matlab - Simulink environment
- Heat balance approach, Apparent heat capacity method
- 3 layers consideration and nodal discretization



- Adaptation for the needs of the tool
- Calculation of temperature at the outlet part of the system

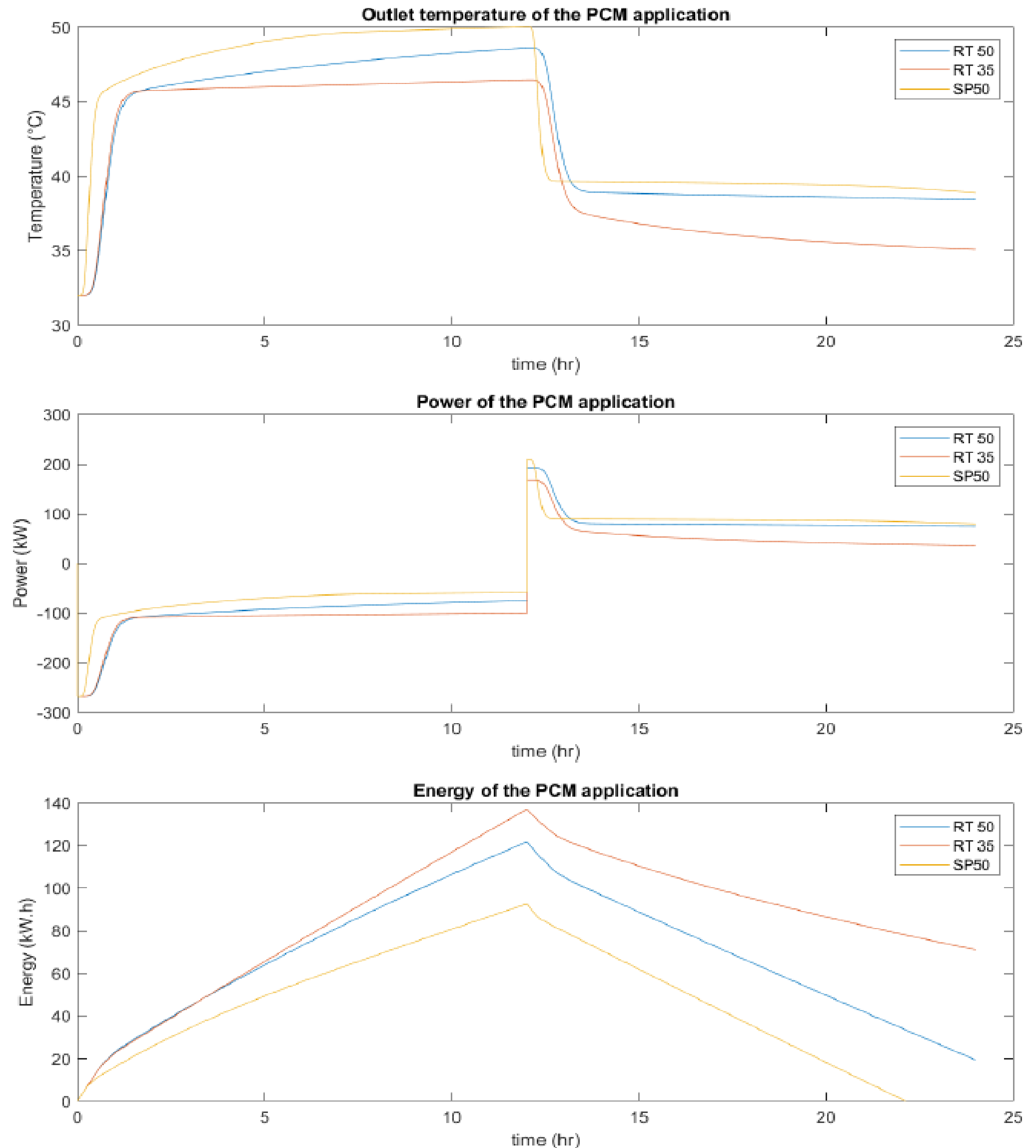
Stathopoulos et al., 2016: *Air-PCM heat exchanger for peak load management: Experimental and simulation*, Solar Energy.

Summary report (PDF file generation)

- **Section 1:** Useful information on the TES-PCM tool
- **Section 2:** Inputs from user (desired characteristics)
- **Section 3:** List of suitable PCMs & respective PCM mass and volume of application
- **Section 4:** General information of the selected PCMs.
- **Section 5:** Key performance aspects of the desired application for all selected PCMs (Tout, P, E)
- **Section 6:** Detailed properties of selected PCMs

Presentation of results: example

Name	Units	RT50	RT35	SP50
Manufacturer		Rubitherm	Rubitherm	Rubitherm
Type		paraffin	paraffin	salt hydrate
Melting range	°C	45 to 51	29 to 36	50 to 51
Melting peak	°C	49	33	50
Solidification range	°C	51 to 46	36 to 31	47 to 48
Solidification peak	°C	50	35	48
Heat storage capacity	kJ/kg	160	160	220
Supercooling *		No	No	2.5
Specific heat capacity	kJ/kg.K	2	2	2
Density solid	kg/l	0.88	0.86	1.25
Density liquid	kg/l	0.76	0.77	1.3
Thermal conductivity	W/(m.K)	0.2	0.2	0.6
Volume expansion	%	12.5	12.5	3.5
Flash point **	°C	>200	167	unknown
Max operating temp	°C	70	65	80
Corrosion		No	No	Yes



In summary

- ❑ TES-PCM design tool for heating / cooling building applications
  ☑ user friendly, ☑ standalone, ☑ free

- ❑ Survey among potential users
  ☑ identification of key characteristics of a TES-PCM system

- ❑ PCM database of commercialized PCMs
  ☑ narrow list of suitable materials for specific case
  ☑ calculate PCM mass and volume of system

- ❑ PCM numerical model
  ☑ simulate the performance of the system for the selected PCMs

- ❑ Results presented in Summary report
  ☑ Table with properties of selected PCMs
  ☑ Graphical representation of proposed system's performance