Technology Collaboration Programme
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IEA Technology Collaboration Programme

International Energy Agency

Technology Collaboration Programme on

Energy Storage (ES TCP)

Storage for renewables and flexibility through standardized use of building mass

Questionnaire: SIMULATION

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Contact:

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Dear madam or sir,

thank you for taking the time to fill out this questionnaire! In order to provide a good overview of available **simulation tools** / simulation **models** dealing with **thermally activated building components**, we require your knowledge and expertise. Please use this opportunity to make your work known or provide useful information for other interested parties about tools or models you use or have experience with.

If you give us your personal information, we can keep in touch and maybe consider you as a co-author in possible publications or reports.

Personal Information *(optional)*	
Name: *(Family name, given name)*:	Arregi, Beñat
E-Mail:	benat.arregi@tecnalia.com
Contact	☒ I am available for follow-up questions

Company / Institution	
Name:	Tecnalia
Country:	Spain
Type:	☐ University / Education ☒ Research Institution ☐ Company using simulation software ☐ Company developing simulation software

Please give feedback on categories of simulation software you are developing and / or using.

We distinguish between two different categories of mathematical models, depending on their intended usage: *Detailed* simulation models should reproduce measurements as precisely as possible and are intended for planning, e.g., in construction. *Simplified* models have reduced complexity and can be used for very fast simulations or even within optimization problems, e.g., in control tasks.

Detailed Simulation

Detailed simulation models are used to predict the behaviour of systems in reality (temperature propagation, heat bridges, constructive stability, humidity, dew points, …) as precisely as possible. They may also be used to test control strategies before implementing them.

The focus is on simulation algorithms and tools either with a special focus on activated building components or which at least can handle them well.

Detailed simulation models are typically part of a software package (TRNSYS, Modelica) or are a dedicated software tool themselves (IDA ICE, …). If your input is more about the method than the tool, please feel free to add information in the “Additional information” field.

If you have experience / information on multiple tools, please feel free to copy the table.

Detailed Simulation Tool / Model		
Name:	VOLTRA	
Homepage:	https://www.physibel.be/en/products/voltra	
Relationship to you:	☐ I / my company are developing this software ☐ I / my company are using this software on a daily basis ☒ I / my company are using this software sporadically ☐ Other:	
License:	☐ Not publicly available; developed in-house, e.g., in research projects ☒ Commercial license ☐ Free software ☐ Open source ☐ Other:	
Type:	☒ Stand-alone software ☐ Library / Plugin for: ☐ Other:	
Co-Simulation Interfaces:	☒ None ☐ FMI / FMU ☐ Custom (e.g., call to DLL) ☐ Other:	
Consideration of TABS:	☒ Components ☒ Ceiling ☒ Wall ☐ Other:	☒ Concrete ☒ Brick ☒ Wood ☐ Other materials:
Method to consider TABS[1]:	☐ Ordinary differential equations (ODE) ☐ Partial differential equations (PDE) ☒ Finite Element Method ☐ Other:	
Scope:	☒ Component ☐ Room ☐ Building ☐ City (quarter) ☐ Other:	
Main application:	*Detailed modelling of the temperature distribution and storage within a 2D or 3D component, typically for design purposes.*	
USP: *(unique selling point)*	*3D geometry, dynamic modelling (heat storage), consideration of thermal bridges*	
Alternatives:	*I haven't used any other thermal modelling tools with dynamic capabilities. TRISCO (3D), PsiTherm (3D) and THERM (2D) are other alternatives but to the best of my knowledge are limited to steady-state so they are not useful for modelling TABS.*	

[1] How are thermally activated building components represented in the simulation? If, for example, the entire slab is considered as one block (1D model), this would correspond to an ODE. If piping space can be considered, it could be either PDE or FEM

Speed: *(approximate time for simulating one day)*	☒ Seconds ☐ Minutes ☐ Hours ☐ Other:
Publications on method:	
Publications on applications:	https://doi.org/10.1016/j.apenergy.2014.03.087 https://doi.org/10.1155/2017/6792621 https://doi.org/10.6110/KJACR.2012.24.3.218 https://doi.org/10.6110/KJACR.2013.25.12.647
Additional Information:	

Detailed Simulation Tool / Model		
Name:	WUFI Pro	
Homepage:	https://wufi.de/en/software/wufi-pro/	
Relationship to you:	☐ I / my company are developing this software ☐ I / my company are using this software on a daily basis ☒ I / my company are using this software sporadically ☐ Other:	
License:	☐ Not publicly available; developed in-house, e.g., in research projects ☒ Commercial license ☐ Free software ☐ Open source ☐ Other:	
Type:	☒ Stand-alone software ☐ Library / Plugin for: ☐ Other:	
Co-Simulation Interfaces:	☒ None ☐ FMI / FMU ☐ Custom (e.g., call to DLL) ☐ Other:	
Consideration of TABS:	☒ Components ☒ Ceiling ☒ Wall ☐ Other:	☒ Concrete ☒ Brick ☒ Wood ☐ Other materials:
Method to consider TABS[2]:	☐ Ordinary differential equations (ODE) ☐ Partial differential equations (PDE) ☒ Finite Element Method ☐ Other: Finite Difference Method	

[2] How are thermally activated building components represented in the simulation? If, for example, the entire slab is considered as one block (1D model), this would correspond to an ODE. If piping space can be considered, it could be either PDE or FEM

Scope:	☒ Component ☐ Room ☐ Building ☐ City (quarter) ☐ Other:
Main application:	*Tentative modelling of the 1D temperature distribution and storage within a component, typically for design purposes.*
USP: *(unique selling point)*	*Relatively user-friendly interface, the software is primarily designed for transient hygrothermal simulations (coupled heat and moisture), but it is possible to use it as a fast tool for 1D dynamic thermal modelling by switching off the hygric calculations.*
Alternatives:	*DELPHIN (https://bauklimatik-dresden.de/delphin/index.php) is a more complete but more research-oriented tool.* *WUFI 2D (https://wufi.de/en/software/wufi-2d/) is a 2D version of WUFI Pro, but it requires greater effort from the modeler and in my experience is not as suitable as WUFI Pro for fast exploratory simulations.*
Speed: *(approximate time for simulating one day)*	☒ Seconds ☐ Minutes ☐ Hours ☐ Other:
Publications on method:	*https://wufi.de/en/wp-content/uploads/sites/11/2014/11/Mundt-Petersen-Harderup-Validation-of-a-One-Dimensional-Transient.pdf* *https://lup.lub.lu.se/search/files/5974170/5212267.pdf*
Publications on applications:	
Additional Information:	

Open Challenges for Detailed Simulation Models
Component-level thermal modelling tools can serve multiple purposes, which is one of their main strengths but at the same time requires expertise from the modeller. These software tools are not specifically designed to model TABS, so specific knowledge from the system is needed (for working temperatures, mass flows, convective effects, etc.).

Simplified Simulation Models / Prediction Models

Simplified simulation models are often resistor/capacitor (RC) equivalent models of a certain order, (linear) state-space models or data-driven models based on Machine Learning / Artificial Intelligence. They are directly used as prediction models in optimization problems or for quick evaluations of scenarios.

Here, the focus is probably less on the tool / software, and more on the **method**.

Specifically, the problem of **parametrization** (based on measurements or derived from more detailed models), the **mathematical complexity** (linear, mixed integer, non-linear) – and thus the ease of integration into optimization problems – are of interest here.

Simplified Simulation Model	
Name:	*(Custom RC modelling)*
Homepage:	
Relationship to you:	☒ I / my company are developing this model ☐ I / my company are using this model on a daily basis ☐ I / my company are using this model sporadically ☐ Other:
License:	☒ Not publicly available; developed in-house, e.g., in research projects ☐ Commercial license ☐ Free software ☐ Open source
Type:	☒ Mathematical model only ☐ Stand-alone software ☐ Library / Plugin for: ☐ Other:
Method / Complexity:	☐ State space / Ordinary Differential Equation (nonlinear) ☒ State space / Ordinary Differential Equation (linear), e.g., RC model ☐ Neural network ☐ Other:
Scope:	☒ Individual room temperature ☒ Multiple rooms / entire building ☒ Multiple buildings ☐ Other:
Main application:	*Dynamic modelling of heat transmission and storage effects at multiple scales: building components (passive / active / adaptive), rooms, entire buildings*
Usage[3]:	☒ Simulation studies ☒ Real-world implementation and control ☐ Other:
USP: *(unique selling point)*	*Versatility, data-driven approach (trained with monitored data) yet keeping (limited) physical interpretability*
Thermally activated components:	☒ Implicitly considered (depending on parametrization) ☒ Explicitly considered ☐ Other: The model can handle it both ways

[3] How has the model/the method been used / what is it intended for?
Simulation studies can give an indication, e.g., on the benefits of using TABS or intelligent controllers. The models they use for control/optimization, however, need not represent a real building, but perhaps only a simplified version of a more detailed model used for validation of the controller. The parametrization and estimation of internal gains etc. are, therefore, possibly simpler.
Real-world implementation and control, on the other hand, requires either a robust control algorithm or a very good match between the model parameters and reality.

Alternatives:	*If you know about similar solutions, please denote them here.* *Ideally, copy this table and fill it out for the alternative as well.*
Phenomena considered:	☒ Ambient temperature ☒ Solar irradiation ☒ Internal gains (preconfigured) ☐ Internal gains (automatically detected) ☒ Shading ☐ Air circulation ☐ Interaction between rooms ☒ Interaction with the energy hub (heat flows, feed temperature,…) ☐ Other:
Parametrization[4]:	☒ Manual ☐ Derived from detailed simulation model: *please indicate possible sources / file formats* ☐ Derived from archetypes ☐ Automatic via historic measurements (controlled operation) ☒ Automatic via historic measurements (specific experiments) ☐ Automatic parameter update (online)
Publications on method:	There are many publications on the subject of linear state space (RC) models
Publications on applications:	*No TABS-related applications*
Additional Information:	

Open Challenges for Simplified Simulation Models
The main challenge for simplified simulation models (RC or other) is the manual input (and associated time and cost) required for parametrization. There is ongoing research (by our team and others) on automatic modelling and parametrization, with the possibility of real-time implementation for operation.

[4] Every model depends on its parameters. Please indicate how they are determined in this model/method.
Manual: The user has to choose the parameters by hand, e.g. by running multiple simulations and adjusting the parameters.
Derived from detailed simulation model: A detailed (building) simulation model is used to parametrize a more simplified model. Example: BRCM Toolbox of ETH Zurich.
Derived from archetypes: The parameters are chosen from a set of pre-defined parameters. This is more suitable for performing simulation studies, but probably not enough for the control of an actual building.
Automatic via historic measurements: The parameters are estimated from historic measurements, e.g., using a least-squares based algorithm or any data-driven method. "*Controlled operation*" means that the algorithm can cope with measurements taken in an already controlled environment, meaning that the room temperatures stay close to the setpoints and little information on the effect of heating/cooling is available. "*Specific experiments*" means that special heat-up / cooldown experiments need to be performed in order to obtain trustworthy parameter estimates.
Automatic parameter update: The parameters are not only estimated once, but continuously adapted based on new measurements. This requires methods ensuring that the parameters do not take on meaningless values.

Thank you for completing the questionnaire! Kindly send back the filled-out form to daniel.muschick@best-research.eu.