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)*:	Pablo Hernandez-Cruz
E-Mail:	pablo.hernandezd@ehu.eus
Contact	☒ I am available for follow-up questions

Company / Institution	
Name:	University of the Basque Country (UPV/EHU) University of Vigo (UVigo)
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. ***Prediction* models** have reduced complexity and can be used for very fast simulations or even within optimization problems, e.g., in control tasks, to predict how changes in the operation influence the temperature and comfort of residents.

Please provide information on one or both of the simulation types, depending on your professional experience.

Note that your responses will be made available to the task participants and may be used in the preparation of official reports that will be made publicly available.

Please send the questionnaire to daniel.muschick@best-research.eu once you have filled it out.
Thank you!

Detailed Simulation Models

Detailed simulation models are used to calculate 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, which may depend on simplified prediction models, before implementing them. The parametrization of the models is done by specifying physical and geometric properties, i.e., It is not necessary to have real measurement data to setup a simulation.

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:		
Homepage:		
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:	☐ Ceiling ☐ Floor ☐ Wall ☐ Other:	☐ Concrete ☐ Brick ☐ Wood ☐ Other materials:

Method to consider TABS[1]:	☐ Ordinary differential equations (ODE) ☐ Partial differential equations (PDE) ☐ Finite Element Method (FEM) ☐ Other:
Scope:	☐ Component ☐ Room ☐ Building ☐ City (quarter) ☐ Other:
Main application:	*Please describe the typical use-case when working with this simulation tool.*
Integration of control:	☐ None (e.g., steady state calculations only) ☐ Controllers defined in model ☐ External control possible with co-simulation interface ☐ Other:
USP: *(unique selling point)*	*What makes this tool better/different from other simulation tools*
Alternatives:	*If you know about similar solutions, please denote them here.* *Ideally, copy this table and fill it out for the alternative as well.*
Publications on method:	*E.g., own publications on the simulation method; review papers.* *For commercial products: Link to publicly available information*
Publications on applications:	*E.g., simulation studies performed with this tool*
Additional Information:	*Please provide any information you consider of interest, e.g., provide details only asked of simplified simulation models*

Open Challenges for Detailed Simulation Models
Please indicate open challenges for detailed simulation models and tools, esp. regarding the correct representation and integration of thermally activated components.

[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

Prediction Models

Prediction models are simplified models that focus on the input/output relationship of thermal zones or buildings, i.e., how different operating strategies will affect the temperature and comfort experienced by the residents. They are directly used as models in optimization problems or for quick evaluations of scenarios. They 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.

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

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

Prediction Model	
Name:	*R-C Model to Control the Heat Pump serving a Radiant Floor*
Homepage:	*(if applicable)*
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:	*The R-C Model represents the system composed by the radiant floor and the room, including energy losses and air leakage. Therefore, the R-C Model accounts for the thermal inertia of the radiant floor and the room. We use the R-C Model to control de set-point of the Heat Pump, so as to optimize the functioning using different control strategies, i.e.: minimize the electricity costs or take advantage of photovoltaic production.*

Usage[2]:	☒ Simulation studies ☐ Real-world implementation and control ☐ Other:
Consideration of comfort[3]:	☒ Indoor air temperature ☐ Surface temperatures ☐ Air draft ☐ Humidity ☐ Other:
USP: *(unique selling point)*	*We are working on the standardization of the derivation of the R-C Model from monitoring data, and the ease of implementation of the control as advantages of this simulation methodology.*
Alternatives:	*If you know about similar solutions, please denote them here.* *Ideally, copy this table and fill it out for the alternative as well.*
Thermally activated components:	☒ Implicitly considered (depending on parametrization) ☐ Explicitly considered ☐ Other:
Phenomena considered:	☒ Ambient temperature ☒ Solar irradiation ☐ Internal gains (preconfigured) ☒ Internal gains (automatically detected) ☐ Shading ☒ Air ventilation ☐ Interaction (heat / air exchange) between the rooms ☒ Interaction with the energy hub (heat flows, feed temperature, …) ☐ Other:

[2] 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.

[3] Good control algorithms should not only consider temperature, but also other comfort parameters.

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:	*" Optimizing Heat Pump Operation of Residential Buildings Using Calibrated R-C and Deep Learning Models and Electricity Costs Forecasts", ISEC 04 Congress (https://www.tib-op.org/ojs/index.php/isec/article/view/1142)*
Publications on applications:	*E.g., simulation or optimization studies performed with this tool/method*
Additional Information:	*Our colleagues of the University of Vigo, Spain, are co-authors of the publication indicated above. They are working on Deep Learning (DL) models to simulate the behaviour of the same radiant floor we are working with. Below, information regarding the DL model used in the aforementioned publication can be found.*

Open Challenges for Prediction Models
We are currently working on: • *Generating synthetic data with the R-C Model to train the ML model* • *Using real time measurements to automatically parametrize the R-C model*

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

[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.

Prediction Model	
Name:	*ML Model to Control the Heat Pump serving a Radiant Floor*
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: Machine Learning Model
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:	*Development of a deep learning (DL) model to reproduce the thermal behaviour of a hot water radiant floor heating system powered by a heat pump in a dwelling. It has been trained with monitored data at an hourly frequency, using the following variables: outdoor temperature, indoor temperature, heating consumption, and temporal variables (time of day). It allows for the prediction of heating demands and indoor room temperatures.*

Usage[5]:	☒ Simulation studies ☐ Real-world implementation and control ☐ Other:
Consideration of comfort[6]:	☒ Indoor air temperature ☐ Surface temperatures ☐ Air draft ☐ Humidity ☐ Other:
USP: *(unique selling point)*	
Alternatives:	
Thermally activated components:	☒ Implicitly considered (depending on parametrization) ☐ Explicitly considered ☐ Other:
Phenomena considered:	☒ Ambient temperature ☐ Solar irradiation ☐ Internal gains (preconfigured) ☒ Internal gains (automatically detected) ☐ Shading ☐ Air ventilation ☐ Interaction (heat / air exchange) between the rooms ☒ Interaction with the energy hub (heat flows, feed temperature, …) ☐ Other:

[5] 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.

[6] Good control algorithms should not only consider temperature, but also other comfort parameters.

Parametrization[7]:	☐ 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:	*" Optimizing Heat Pump Operation of Residential Buildings Using Calibrated R-C and Deep Learning Models and Electricity Costs Forecasts", ISEC 04 Congress (https://www.tib-op.org/ojs/index.php/isec/article/view/1142)*
Publications on applications:	
Additional Information:	

Open Challenges for Prediction Models
We are currently working on: • *White-box model to generate synthetic data for training ML models, so that the training dataset includes information about situations that do not represent reality (e.g., out-of-range temperature setpoints), allowing the results to be extended to singular cases.*

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

[7] 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.
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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.