Energy management system for a community of buildings

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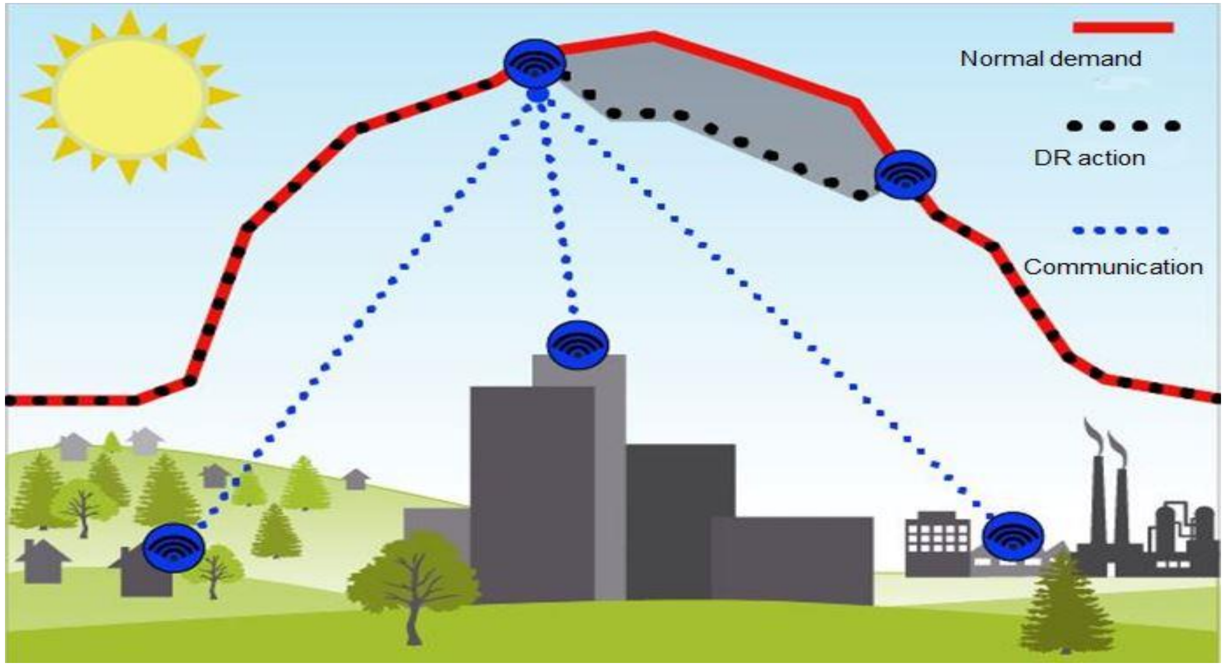
26 April 2022

Introduction

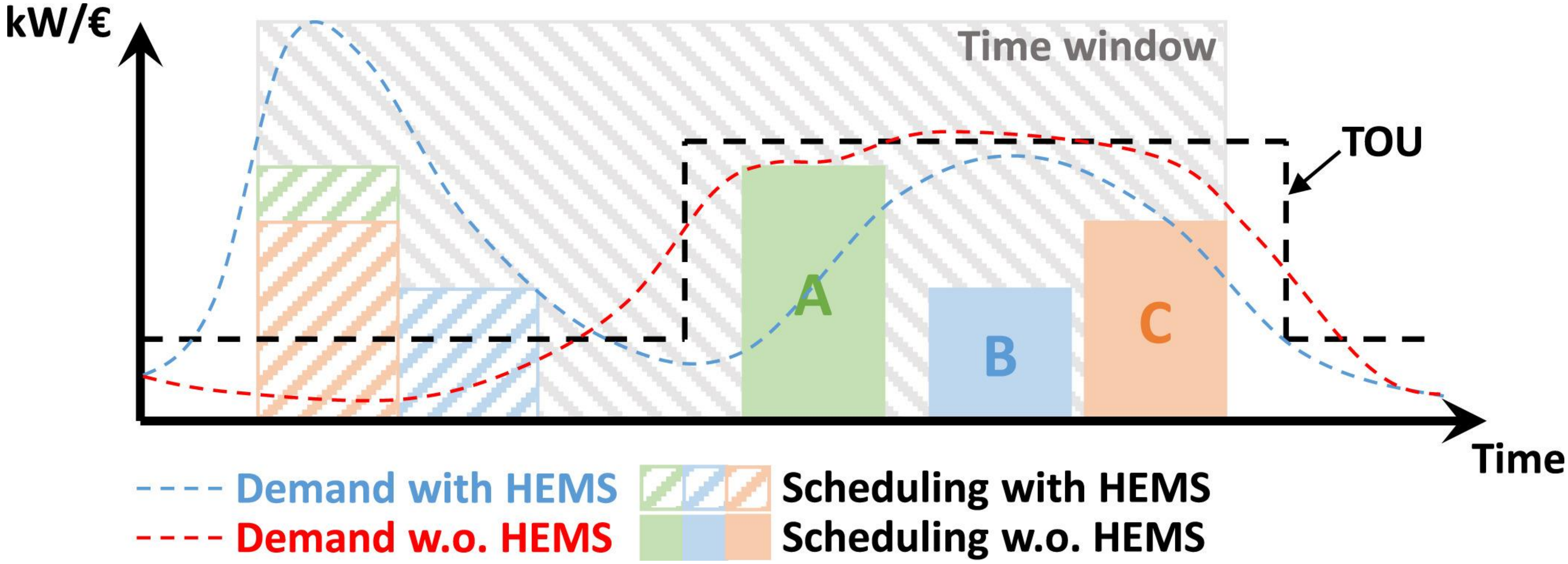
Demand Response

Demand response (DR) control on buildings has been widely accepted as an effective method to reduce or minimize energy consumption and/or cost.



Introduction

Demand Response



Examples

Demand Response in a building

Method:

E+ and IDA ICE building simulation tools, MATLAB, Different rule-based and model-based predictive DRs

Building:

Two different types of structures Lightweight 1960s and Massive Passive

Two-story building (180 m2) with the area of each zone and window

Internal heat gain:

Equipment, lighting, occupancy profiles

Standards (thermal comfort):

European standard EN 15251, and ASHRAE standard 55

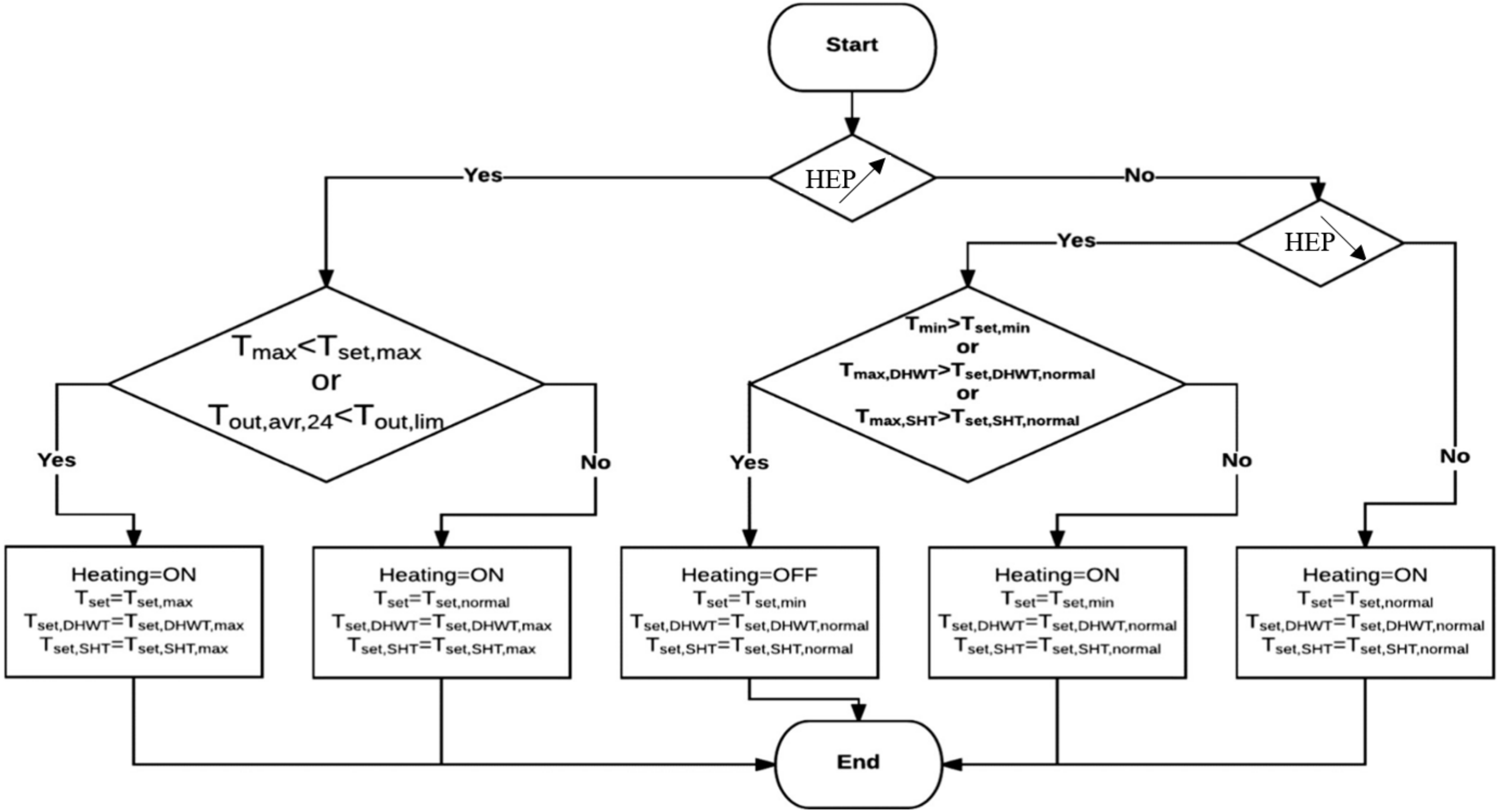
Weather:

Finland TRY 2012 and UK RWD

Hourly electricity price

Examples

Demand Response in a building



Results

- Andreas D. Georgakarakos, **Behrang** Vand, Elizabeth Abigail Hathway, Martin Mayfield. Dispatch Strategies for the Utilisation of Battery Storage Systems in Smart Grid Optimised Buildings. (Buildings, 2021, https://doi.org/10.3390/buildings11100433).
- **Behrang** Vand, Reino Ruusu, Ala Hasan, Benjamin Manrique Delgado. Optimal management of energy sharing in a community of buildings using a model predictive control. (Energy Conversion and Management, 2021, https://doi.org/10.1016/j.enconman.2021.114178).
- **Behrang** Vand, Kristian Martin, Juha Jokisalo, Risto Kosonen, Aira Hast. Demand response potential of district heating and ventilation - An educational building case study. (Science and Technology for the Built Environment, 2019, https://doi.org/10.1080/23744731.2019.1693207).
- Vahid Arabzadeh, **Behrang** Alimohammadisagvand, Juha Jokisalo, Kai Sirén. A novel cost-optimising demand response control for a heat pump heated residential building. (Building Simulation, 2017, https://doi.org/10.1007/s12273-017-0425-5).
- **Behrang** Alimohammadisagvand, Juha Jokisalo, Kai Sirén. Comparison of four rule-based demand response control algorithms in an electrically and heat pump heated residential building. (Applied Energy, 2017, https://doi.org/10.1016/j.apenergy.2017.10.088).
- **Behrang** Alimohammadisagvand, Juha Jokisalo, Simo Kilpeläinen, Mubbashir Ali and Kai Sirén. Cost-optimal thermal energy storage system for a residential building with heat pump heating and demand response control. (Applied Energy, 2016, http://dx.doi.org/10.1016/j.apenergy.2016.04.013).
- **Behrang** Alimohammadisagvand, Sadaf Alam, Mubbashir Ali, Merkebu Degefa, Juha Jokisalo and Kai Sirén. Influence of energy demand response actions on thermal comfort and energy cost in electrically-heated residential houses. (Indoor and Built Environment, 2015, http://dx.doi.org/10.1177/1420326X15608514).

Examples

Demand Response in a building

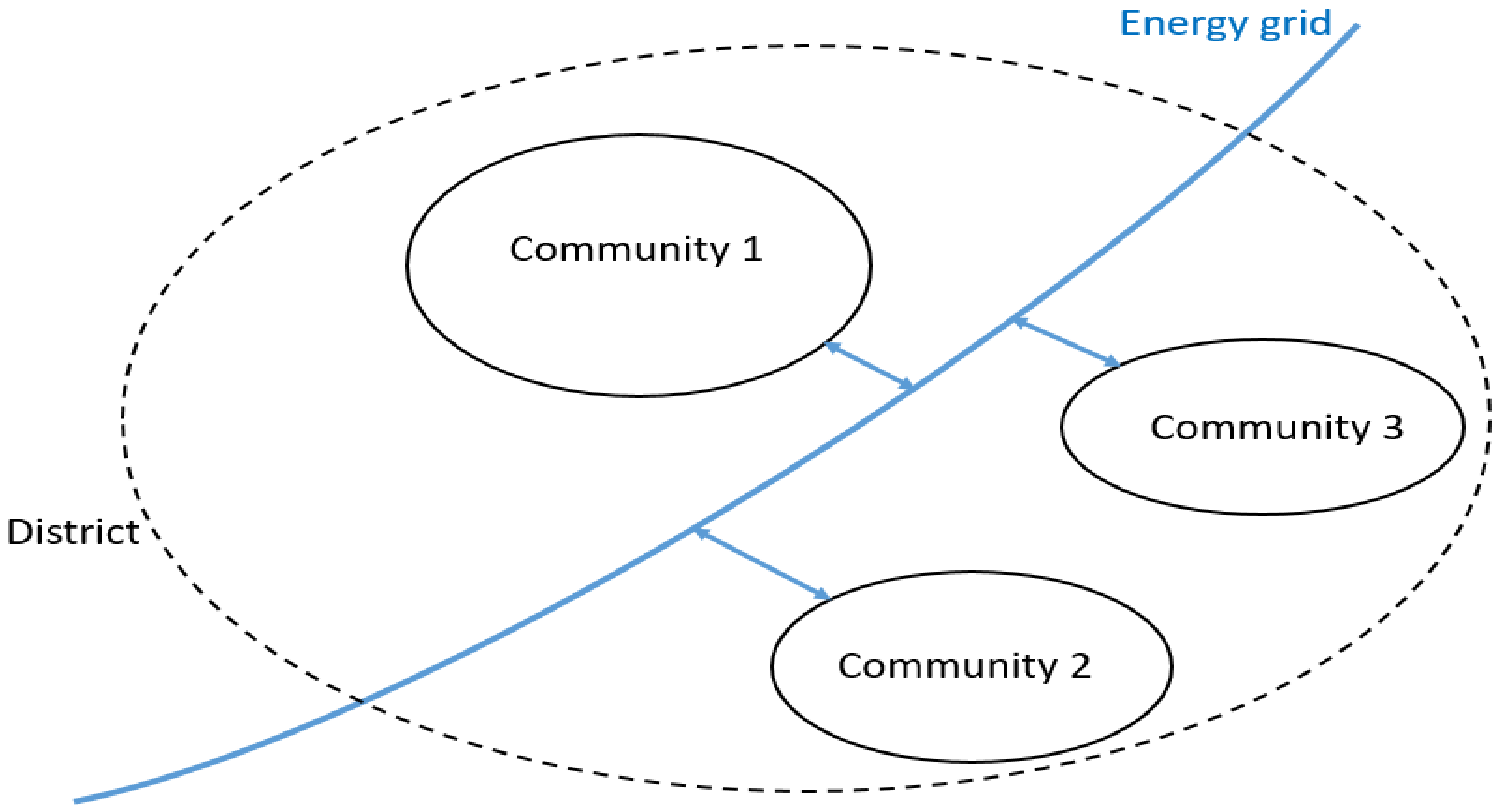
- All presented DR control algorithms maintained the indoor temperature at an acceptable level for occupants.
- The performance of the control algorithms depends on the heat distribution system, controller type and the parameters of the control algorithm.
- The effect of the control algorithm does not depend significantly on the thermal mass of the building structure.
- The results of several proposed DR control algorithms showed that all presented ones were able to reduce the heating energy demand.
- The rule-based DR control algorithm was able to reduce the electricity cost by around 15% and the model-based predictive DR control algorithm did this by 12% in the best cases.

EMS at a community level / Questions

Solar thermal panel

Photovoltaics panel

EMS at a community level



EMS at a community level

Method:

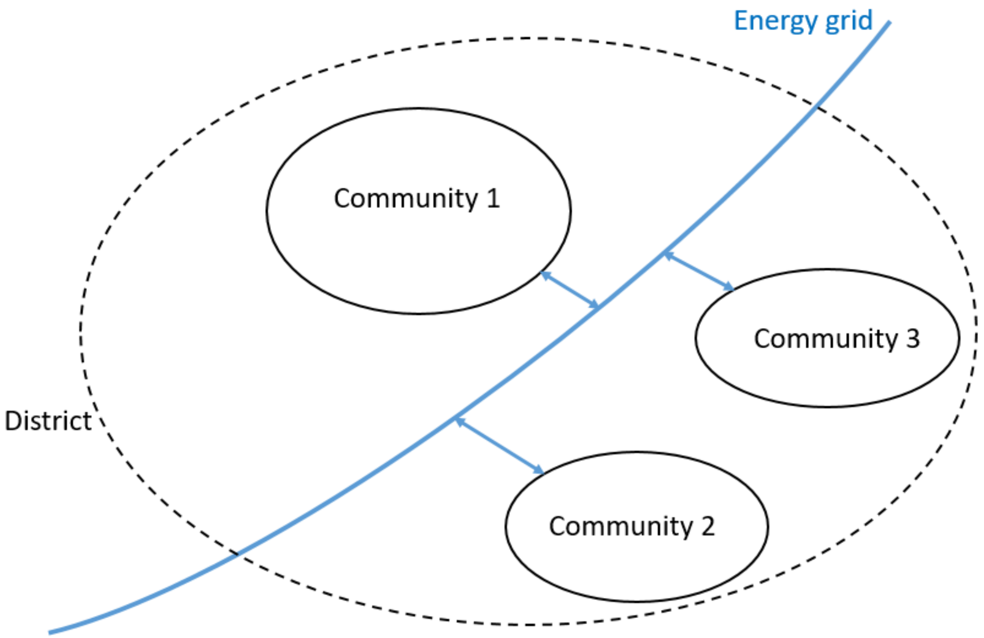
IDA ICE and TRNSYS building simulation tool

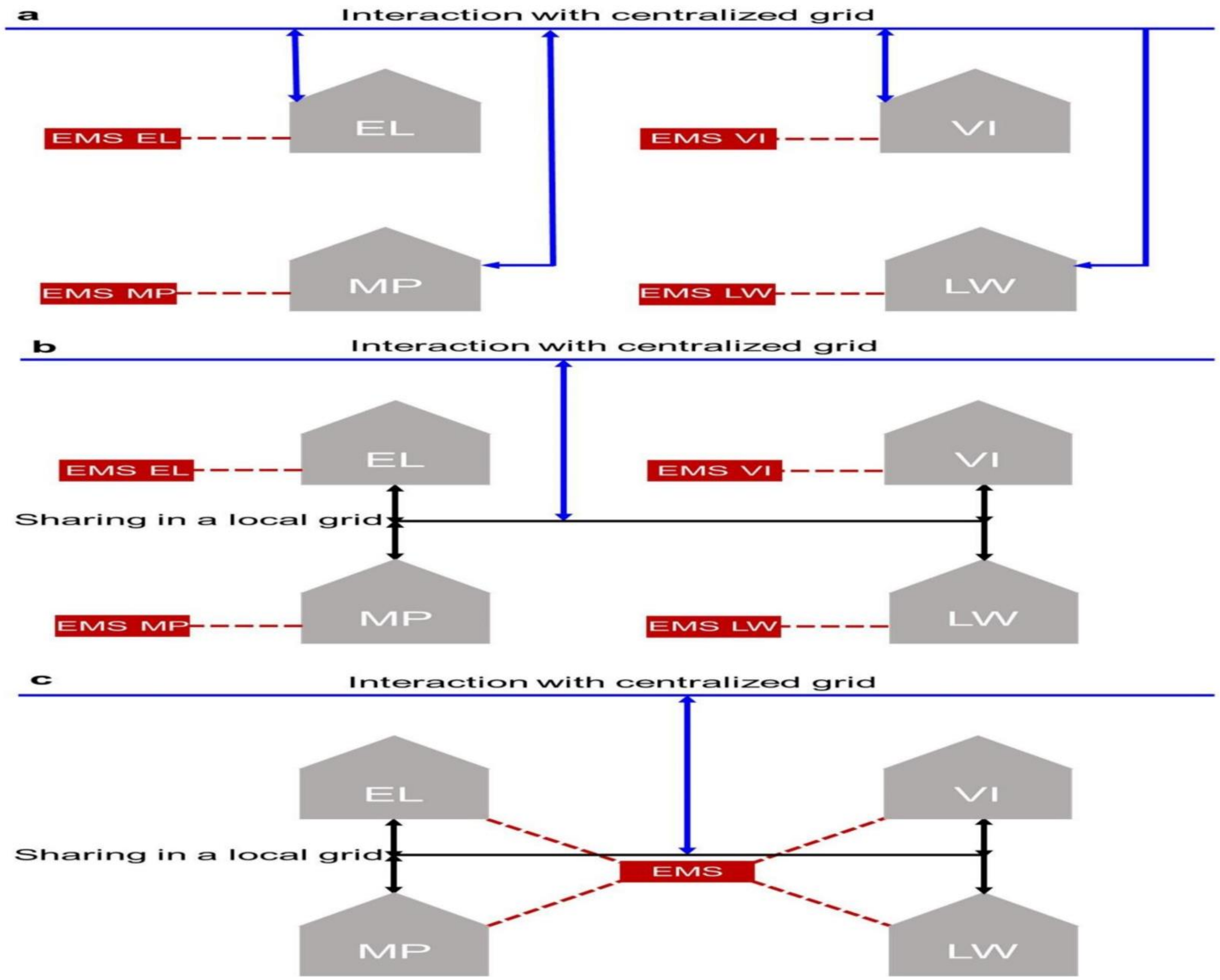
non-linear economic model predictive control and successive linear programming, MATLAB

Buildings' key parameters.

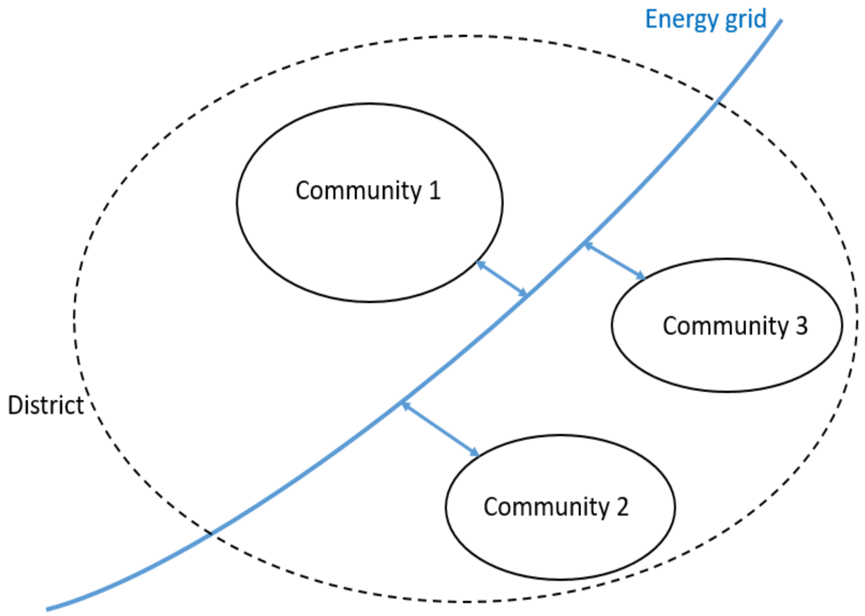
Description	Building			
	EL	VI	MP	LW
Building code regulations	D3 Nearly-zero energy house	D3 Zero-energy house	RIL 249 – 2010 Low energy construction	176/2013 1960s house specifications
Net floor area (m^2)	150	175	180	180
No. of occupants	4	4	4	2
Heat delivery system	Hydronic radiators	Hydronic radiators	Hydronic underfloor	Direct electric radiators
Space heating demand ($kWh/a.m^2$)	33.3	21	11.9	150.9
Domestic Hot water demand ($kWh/a.m^2$)	33.5	13.3	39.4	19.8
Electricity demand ($kWh/a.m^2$)	30.1	29.3	32.8	30.1
Battery capacity (kWh)/Efficiency	20/60%	N.A.	N.A.	N.A.
Hot Water Storage Tank HWST (Litre)	500	750	500	300
GSHP heating (kW)/COP	4.5/3	6.3/3	N.A.	N.A.
In-tank electric heater power (kW)	4	4	2	4
PV power (kWp)	4.32	9.36	N.A.	N.A.
Solar-thermal panel area (m^2)	8.6	6	N.A.	N.A.
Nominal wind turbine power (kW)	4	N.A.	N.A.	N.A.
micro-CHP (heat/electricity)	N.A.	N.A.	Full capacity (9 kW/3 kW), 50% capacity (4.5 kW/1.5 kW)	N.A.

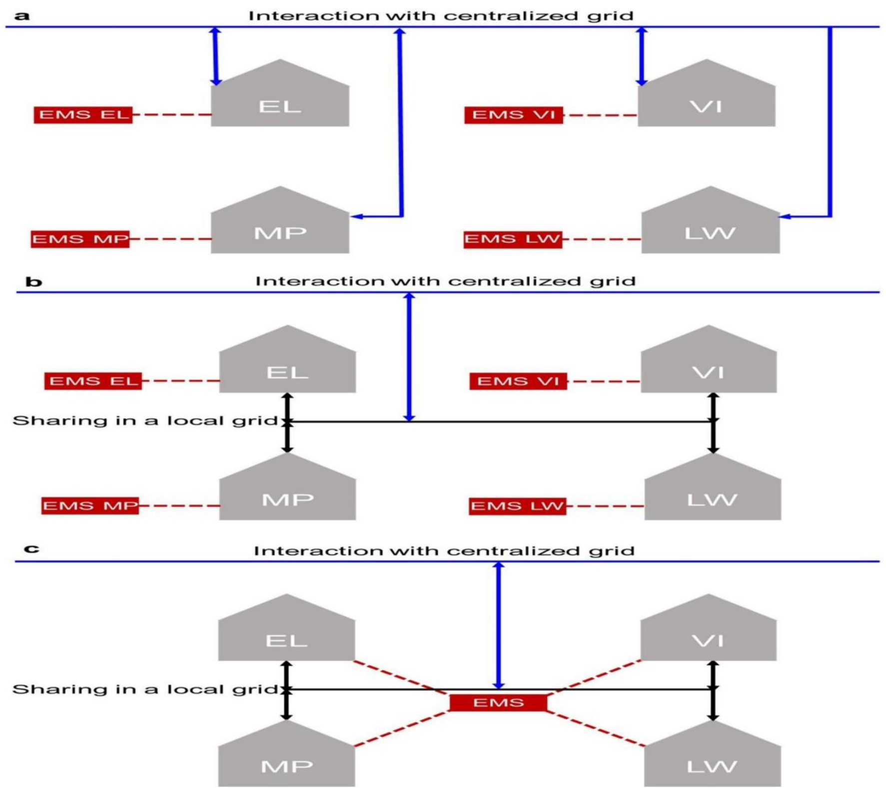
EMS at a community level





EMS at a community level



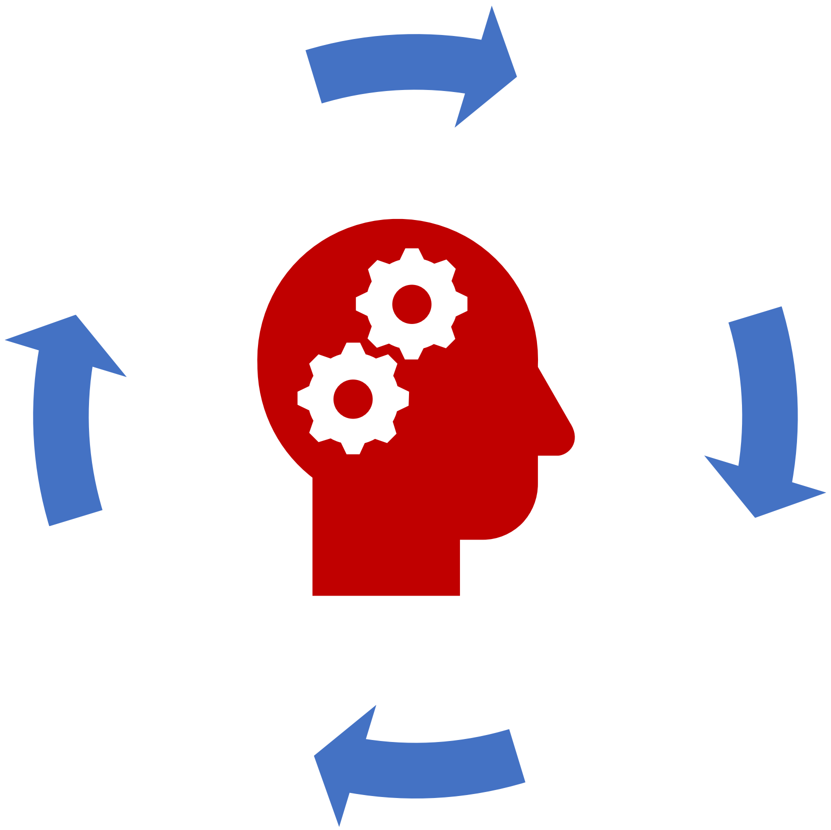


Three different scenarios of the energy management system for the studied community are investigated, and the results indicate that the annual electricity energy cost for single buildings can be reduced by **3.0% to 87.9%**, depending on the building and its systems, and by **5.4% to 7.7%** on the community level.

Energy Conversion and Management 239 (2021) 114178

EMS at a community level - Challenge

Building Modelling



EMS

EMS at a community level

The need is a framework of

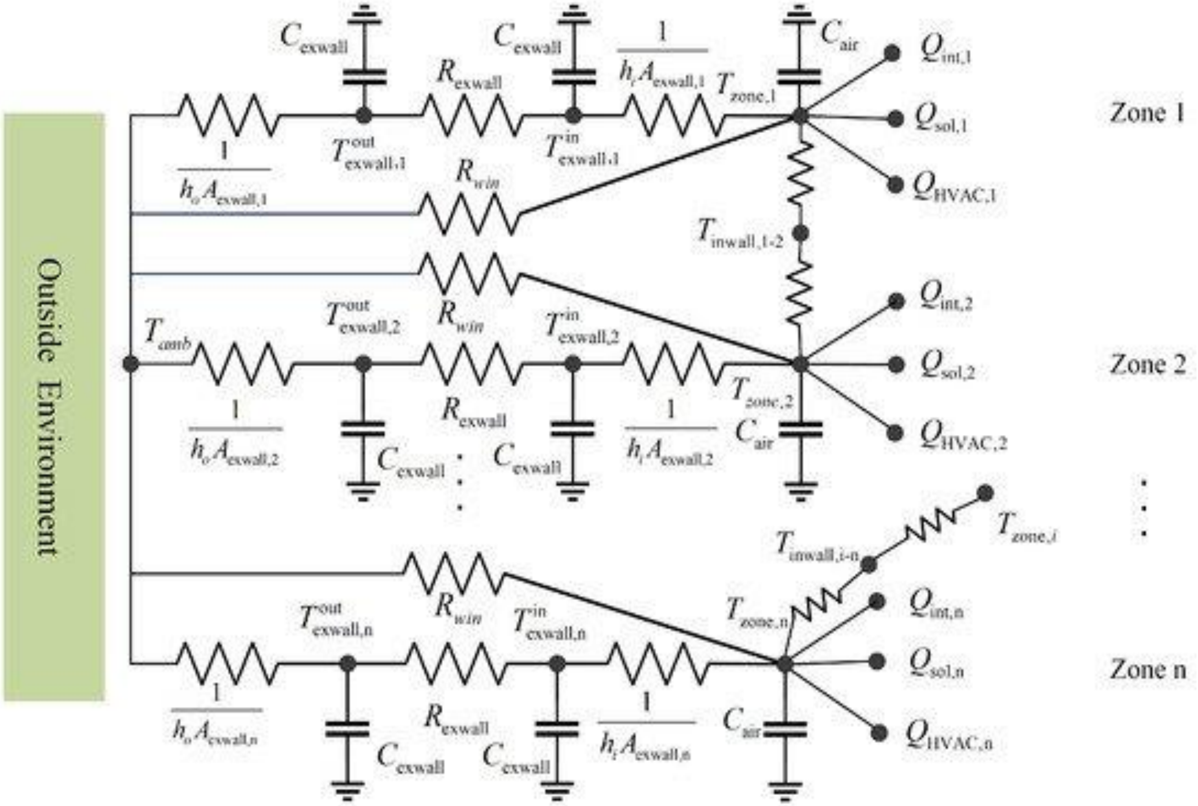
- *Mathematical Models of Building Physics and Energy Technologies Integrated Energy Management Systems*

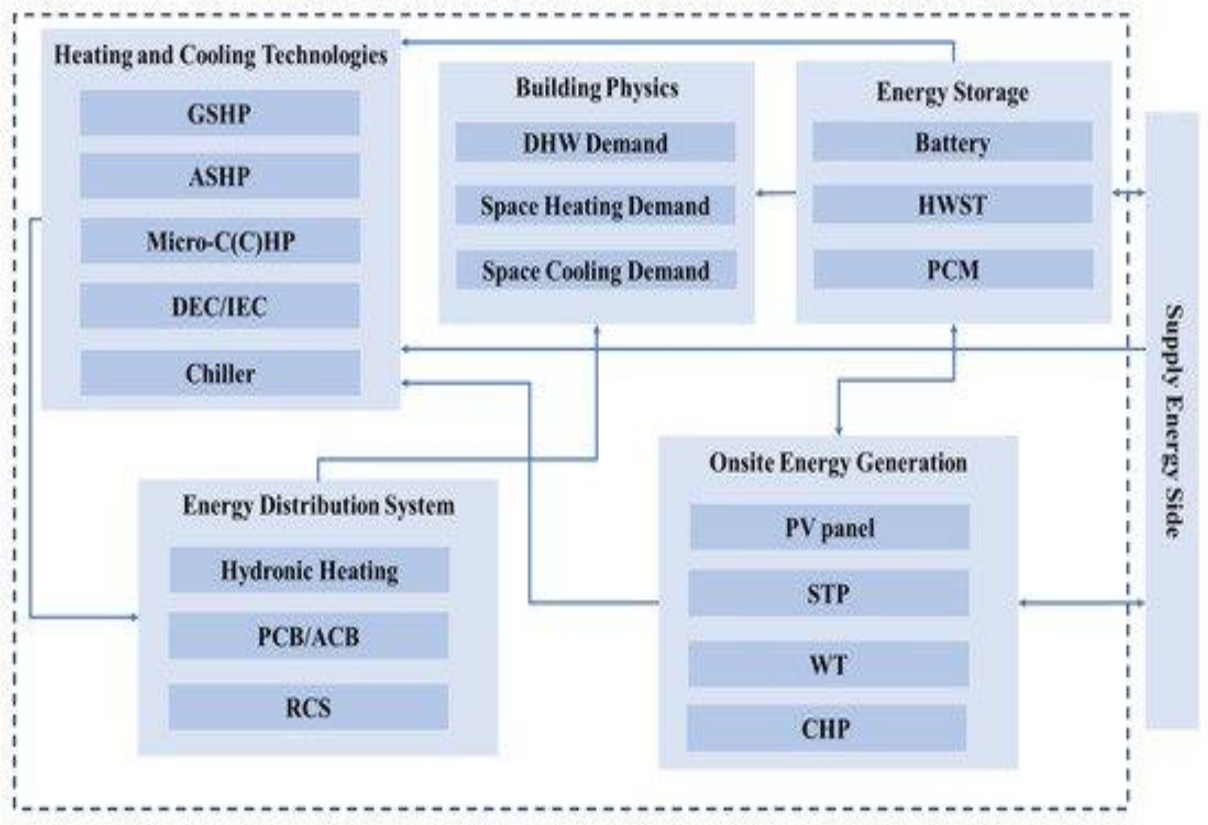
This framework should be designed by simplified but accurate models of building physics and building energy technologies and should allow for the selection of proper control strategies according to the control objectives and scenarios. Therefore, it is formed by

- building physics
- popular building energy technologies (renewable energy systems, common heating and cooling energy systems and energy distribution systems)

Buildings 12(2), 238

EMS at a community level





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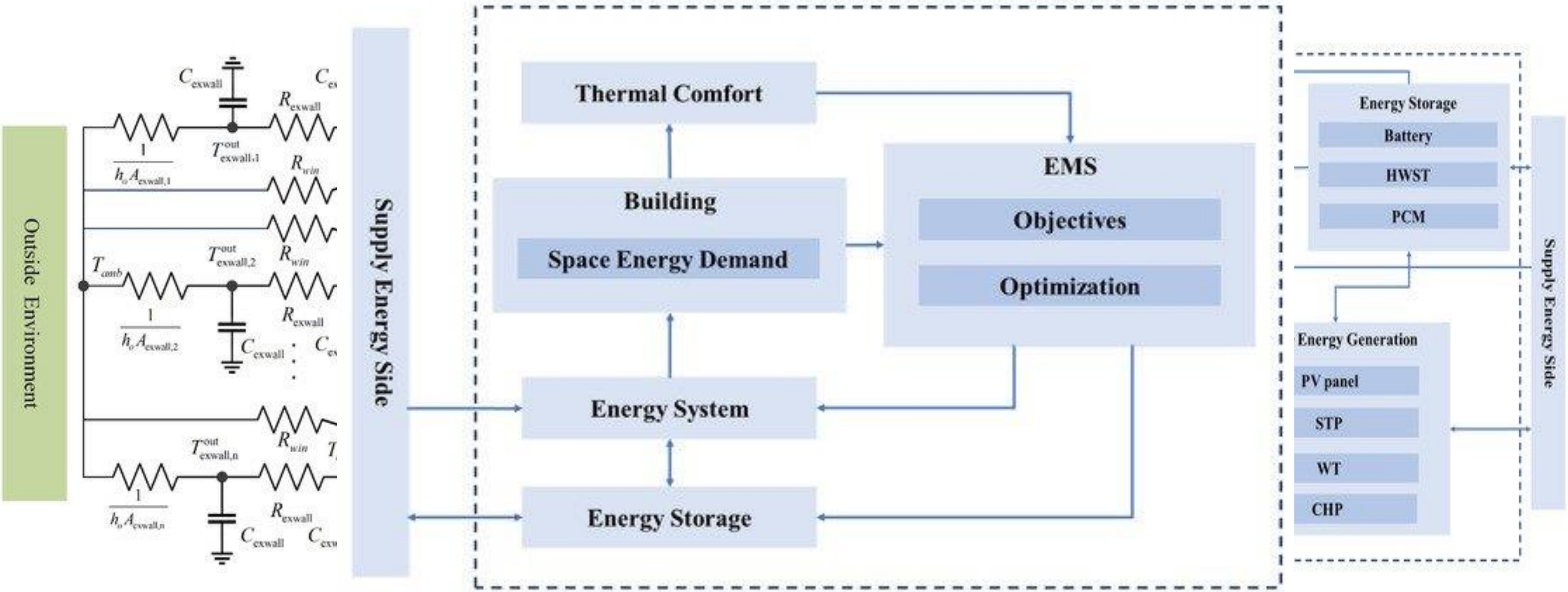
EMS at a community level



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EMS at a community level – Ongoing research

- Second energy price
- Energy technologies
- Size of a community
- Energy policy
- …

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