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Advanced Energy Management to Effectively Utilize Buildings' Renewable Energy Generation and Storage Capabilities

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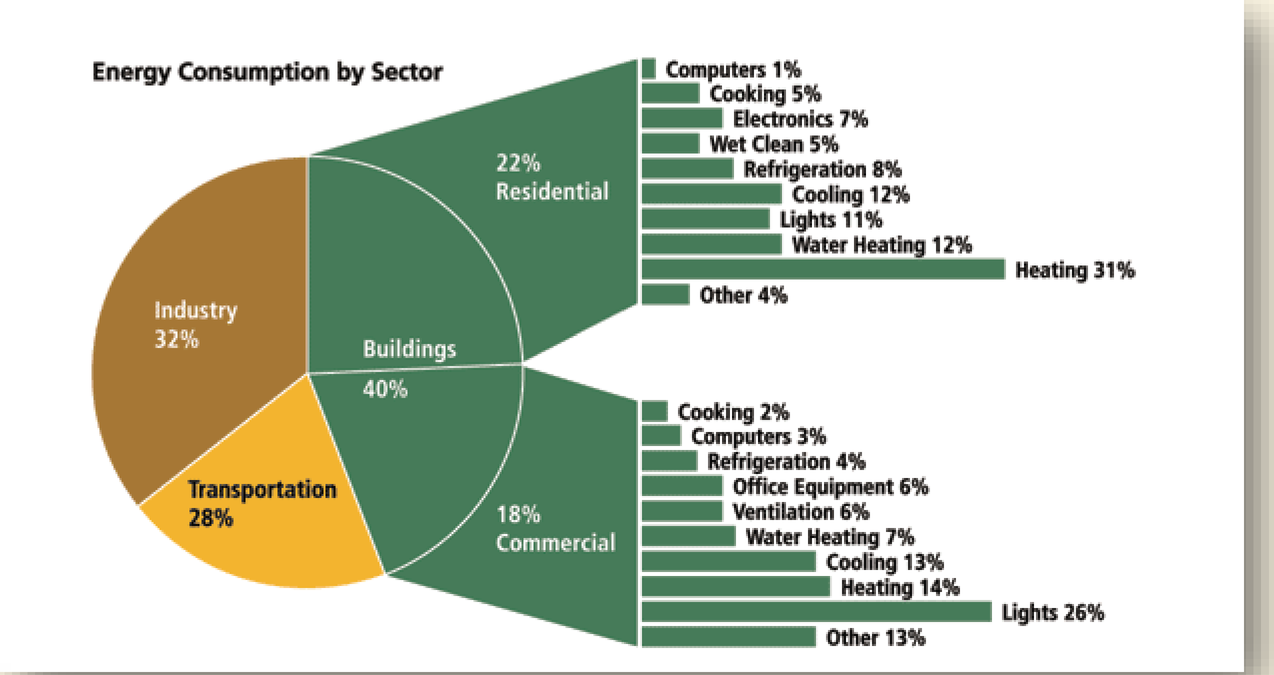
Outline of the presentation

- Overview of the problem
- Aim of the project
- Overview of the proposed system
- Algorithmic model of the Building Virtual Power Plant (BVPP)
- Simulation results
- Conclusions

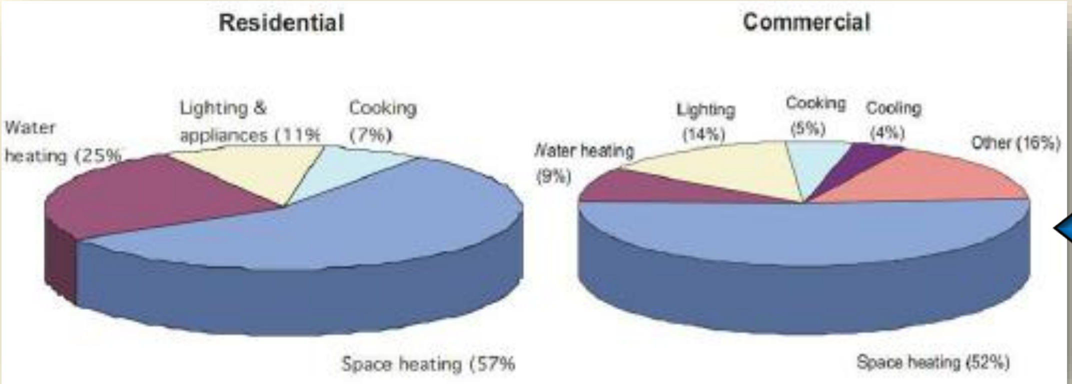
Overview of the problem

Buildings account for nearly 40% of global energy consumption

and the trend is increasing in the next decades, as a result of rapid economy growth



United Nations Environmental Programme, Sustainable Buildings and Climate Initiative, Paris, 2009.



EU building energy consumption for residential and commercial buildings, ICF, Irish Concrete Federation, 2008

From the energy in a building:

- **almost 40% is consumed by HVAC and**
- **15% is consumed by lighting systems)**

Overview of the problem

The three main steps for achieving a **nZEB** target are:

Step 1 (passive design strategies)

- building envelope,
- orientation,
- geometric/ratios,
- cooling strategies

(e.g. solar shading roof, natural ventilation)

- thermal energy storage
- daylighting

Step 2 (energy efficiency technologies)

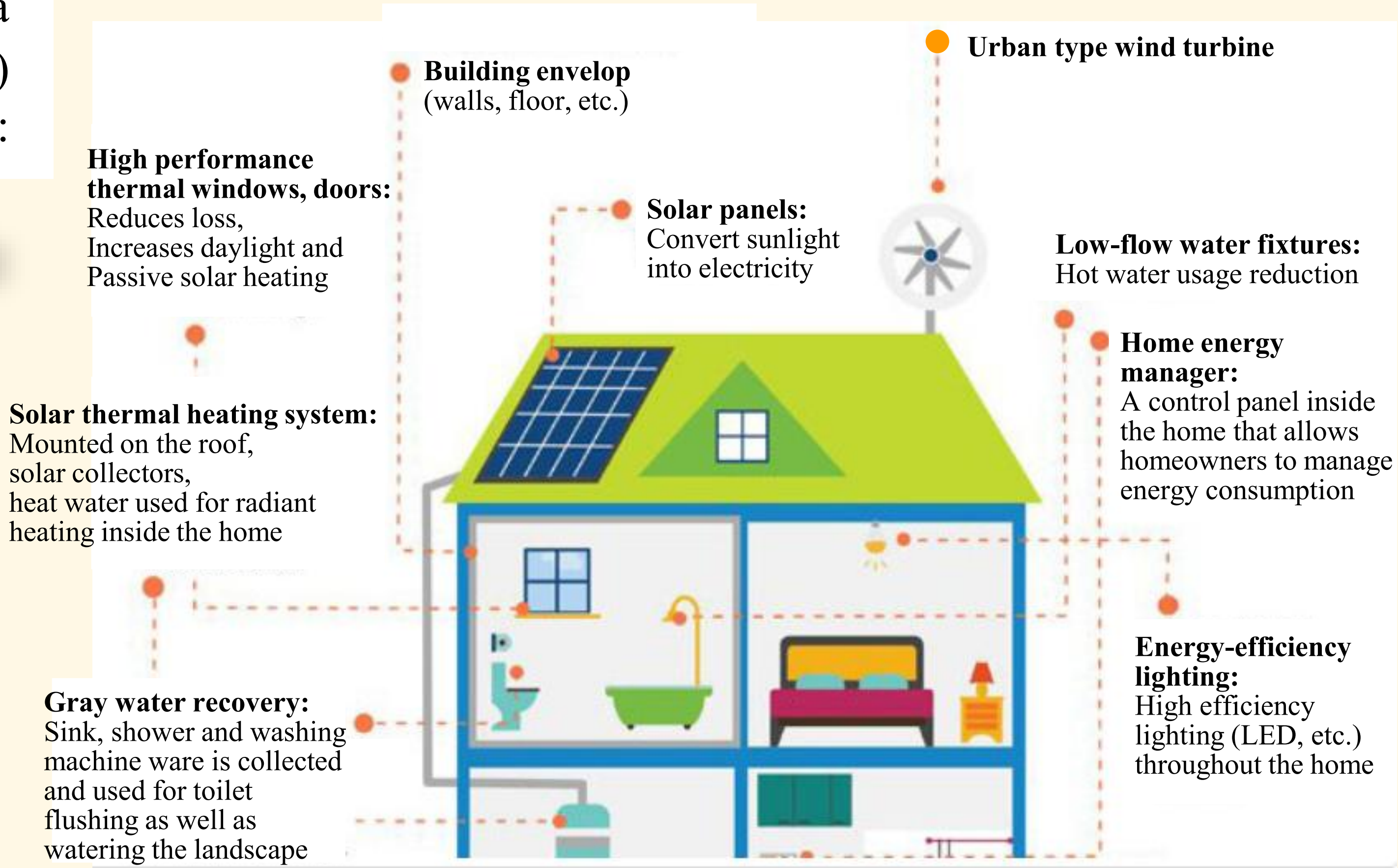
- **H**eat **V**entilation **A**ir Conditioning (**HVAC**)
- Hot water
- Lighting
- Appliances and equipment

Step 3 (energy generation technologies)

- Combined cooling and/or heat and power,
- fuel cells,
- hydroelectric power,
- photovoltaic panel,
- wind turbine
- Solar collector,
- Geothermal heat-pumps

Overview of the problem

Specifically, the features of a **nZEB** (**n**early **Z**ero **E**nergy **B**uilding) are:



Overview of the problem

Basic Design Principles of nZEBs in Scoping and Conceptual Design

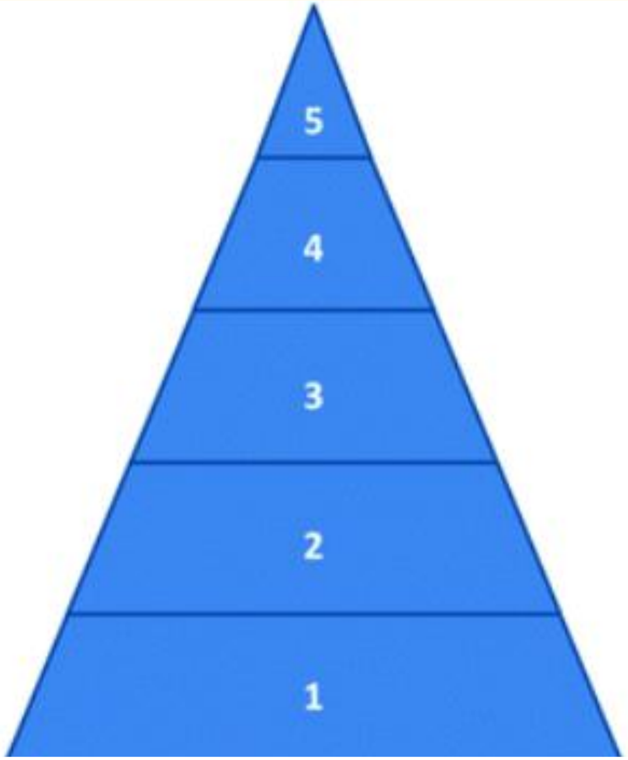
5 On site renewables

4 Energy supply

3 Efficient technical systems

2 Facade design

1 Mass & form
orientation, shape & fabric



Overview of the problem

However, the progress for converting conventional buildings to nZEBs ***is slower** than expected*

... because the ***need for market ready cost reduction solutions*** are required.

Challenges that stimulate solutions:

- ✓ Significant cost reduction could be attained by ***improvements in control processes*** rather than equipment technologies.
- ✓ ***Cost-effective integration of renewable energy production*** elements into nZEB in a form that fits with the construction industry's design and procurement.
- ✓ It is required ***to look beyond nZEB performance*** with a longer term perspective.
- ✓ The new solutions should ***encourage the role that the users and residents*** may play in the building's energy performance.

Overview of the problem

How *can be reduced the investment cost* for converting a conventional building to a nZEB?

Up to now, the efforts are towards:

- the ***reduction of the manufacturing cost of the renewable energy sources*** (RES) and
- seeking for ***cost-effective construction cha***nges in the building.

Overview of the problem

How *can be reduced the investment cost* for converting a conventional building to a nZEB?

However, considerable cost reduction can be achieved by means of:

(a) the ***optimal design of the composition of the renewable energy sources (RES) and energy storage systems (ESS)*** and

(b) the ***combined control and energy management*** of the RES, ESS and energy consumption devices, in order to attain their optimal exploitation and effective utilization.

Overview of the problem

How *can be reduced the investment cost* for converting a conventional building to a nZEB?

Therefore,

although the energy needs of a building are the same in the level of usage and comfort of the residents

the power requirements of the RES and ESS can be reduced that respectively results to cost reduction.

Aim of the project

Main features of the new product:

InREB

- ✓ ***Integrates an optimal design*** methodology with an ***improved control technique*** for the renewable energy sources (RES), energy storage systems (ESS) and electric energy consumption devices that can achieve ***reduction in the power requirements*** of the RES and ESS and therefore ***reduction in the investment cost*** for converting an existing building to an near zero-energy building.
- ✓ The ***construction interventions in a building for energy loss reduction can act complementary*** in the energy saving attained by the InREB.
- ✓ The InREB ***system will have generalized structure*** in order to be applied to any building construction.

Aim of the project

The new product (InREB) consists of:

(a) the ***optimal design software*** for the renewable energy sources composition and

(b) the ***optimal control system*** (software and hardware) of the renewable energy sources, energy storage systems (batteries) and the electric energy consumption devices.

The new product (InREB) is developed in two versions:

- ✓ per building and
- ✓ for several buildings that compose a Building Virtual Power Plant (***BVPP***).

Aim of the project

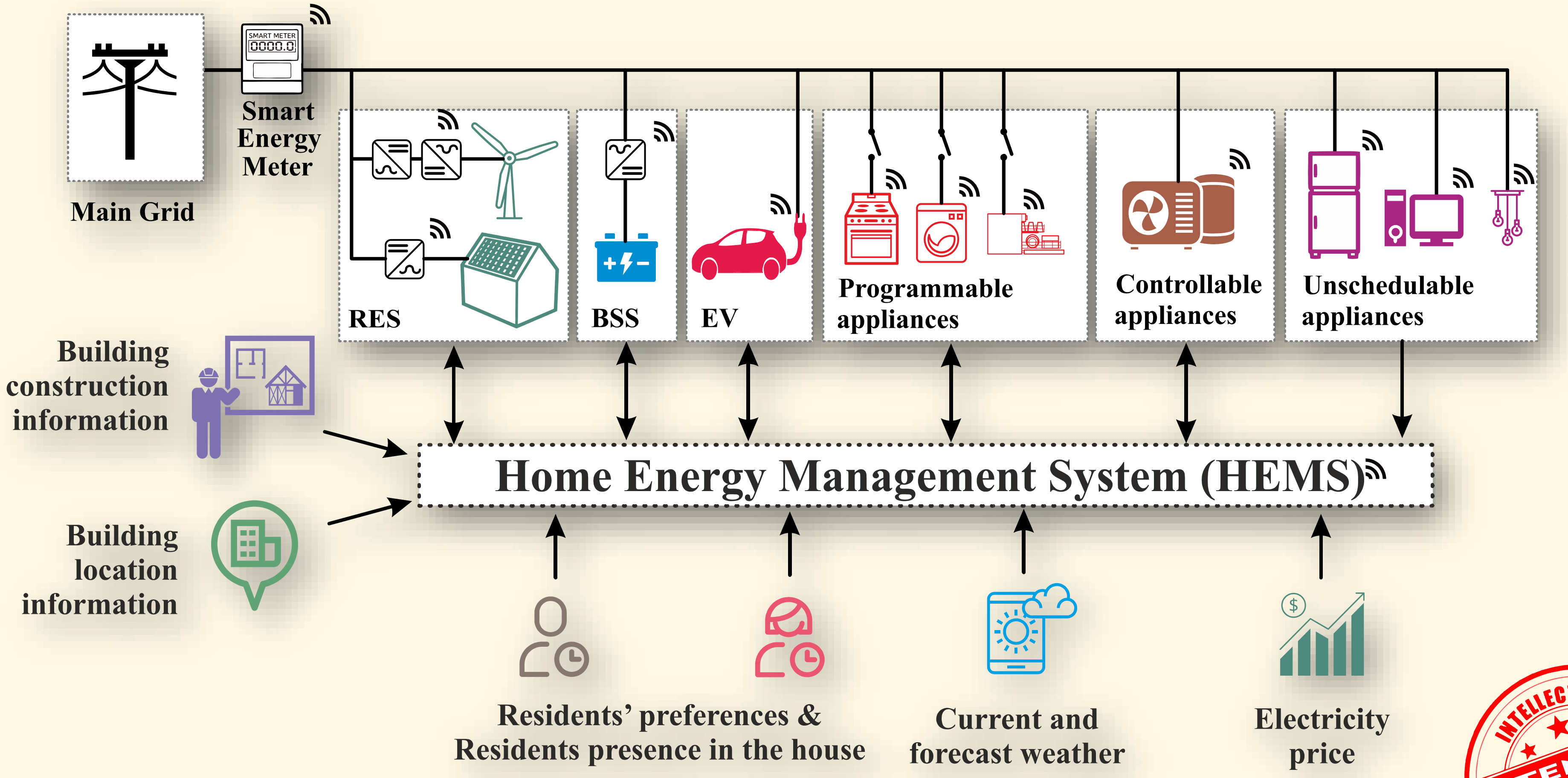
The efficiency improvement
can be attained by the:

- ❑ proper power control and energy management, time sifting, and time scheduling of the electric appliances,
- ❑ proper control of the ESS (batteries) as for, the direction of the energy flow (charging/discharging) and the amplitude of the current and
- ❑ proper power control and energy management of RES

All the above are controlled by considering:

- the comfort and habits/customs/way of life of the residents/consumers
- the electricity price (in online mode),
- the state of charge (SoC) and state of health (SoH) of the batteries,
- the model of the microgrid of the building/apartment,
- short- and long-term prognosis of the generated energy by the RES
- short- and long-term prognosis and programing of energy consumption by the appliances

Overview of the proposed system



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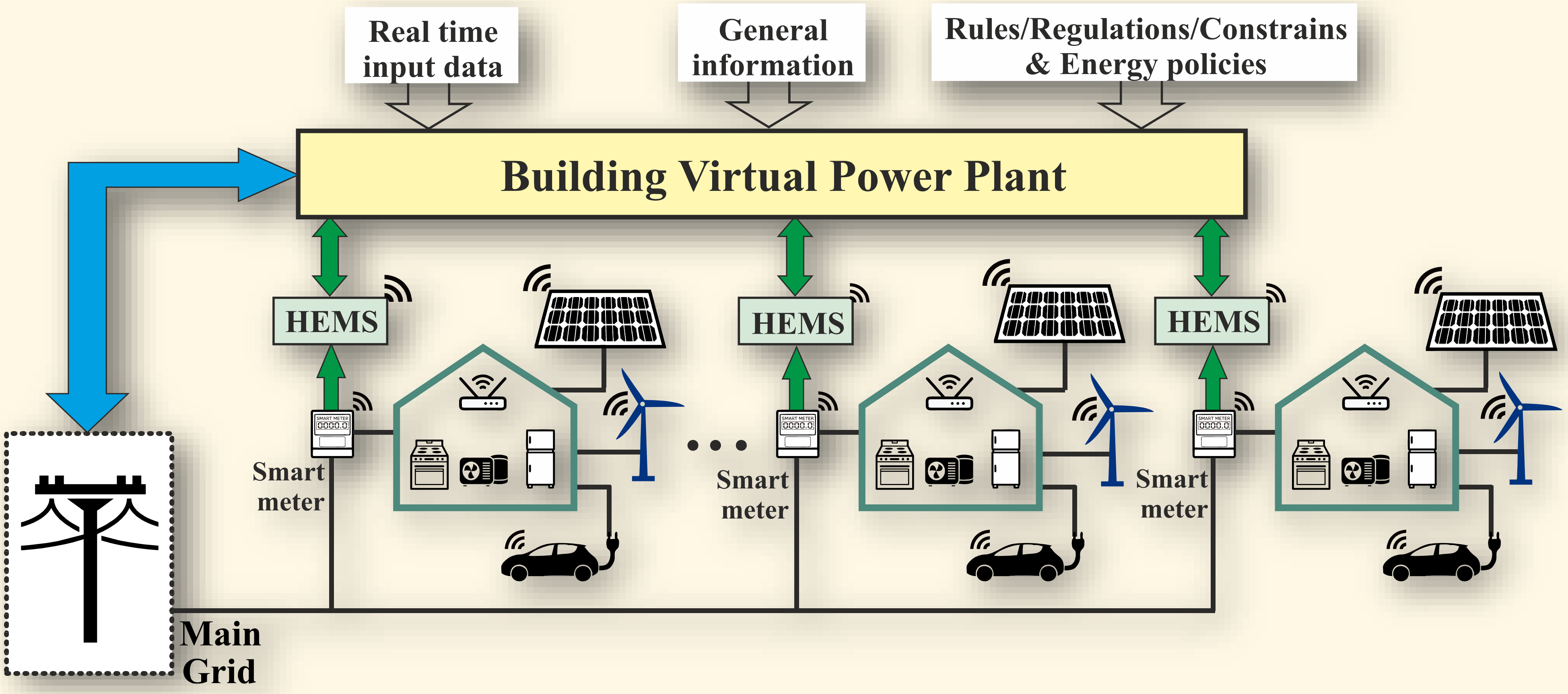
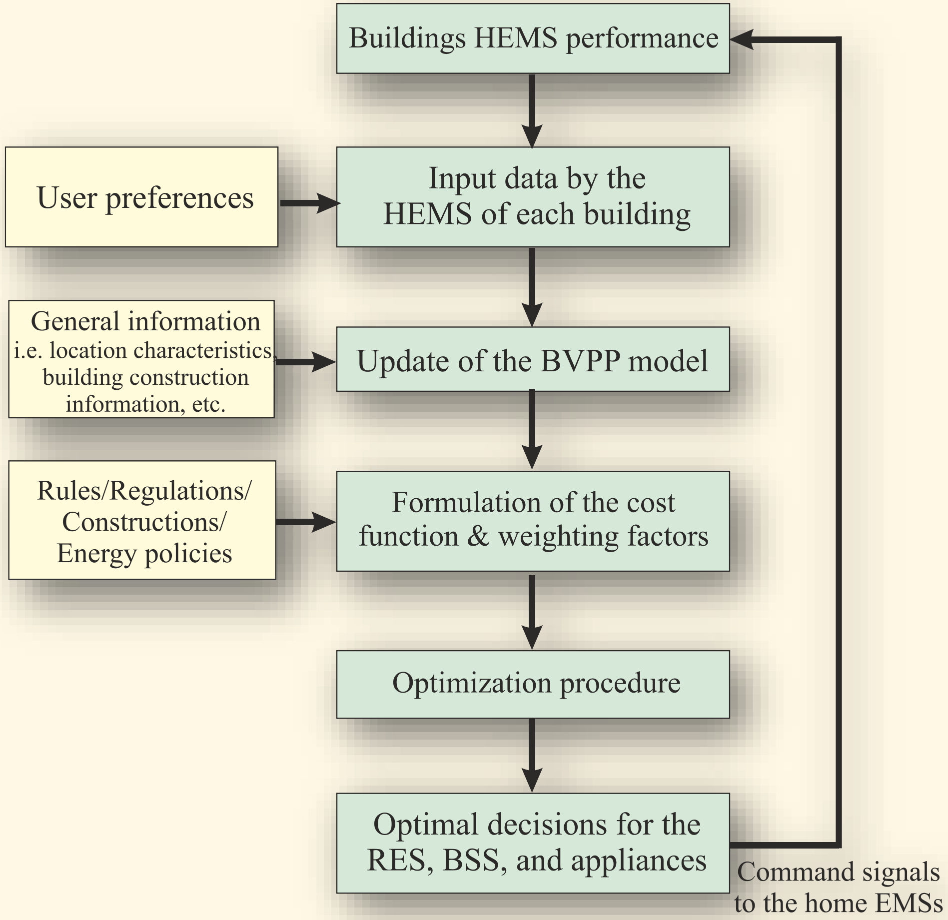
(Schematic representation of the overview of the home EMS of each building)

Overview of the proposed system

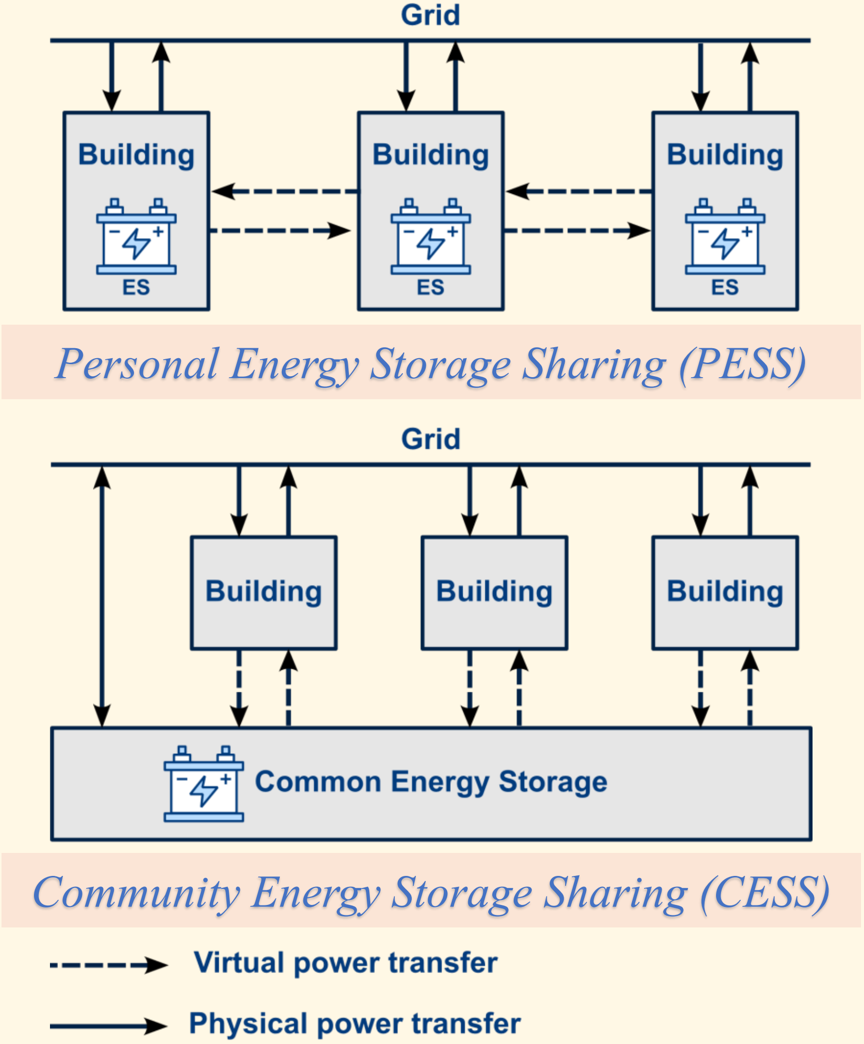


(Schematic representation of the overview of the BVPP-EMS)

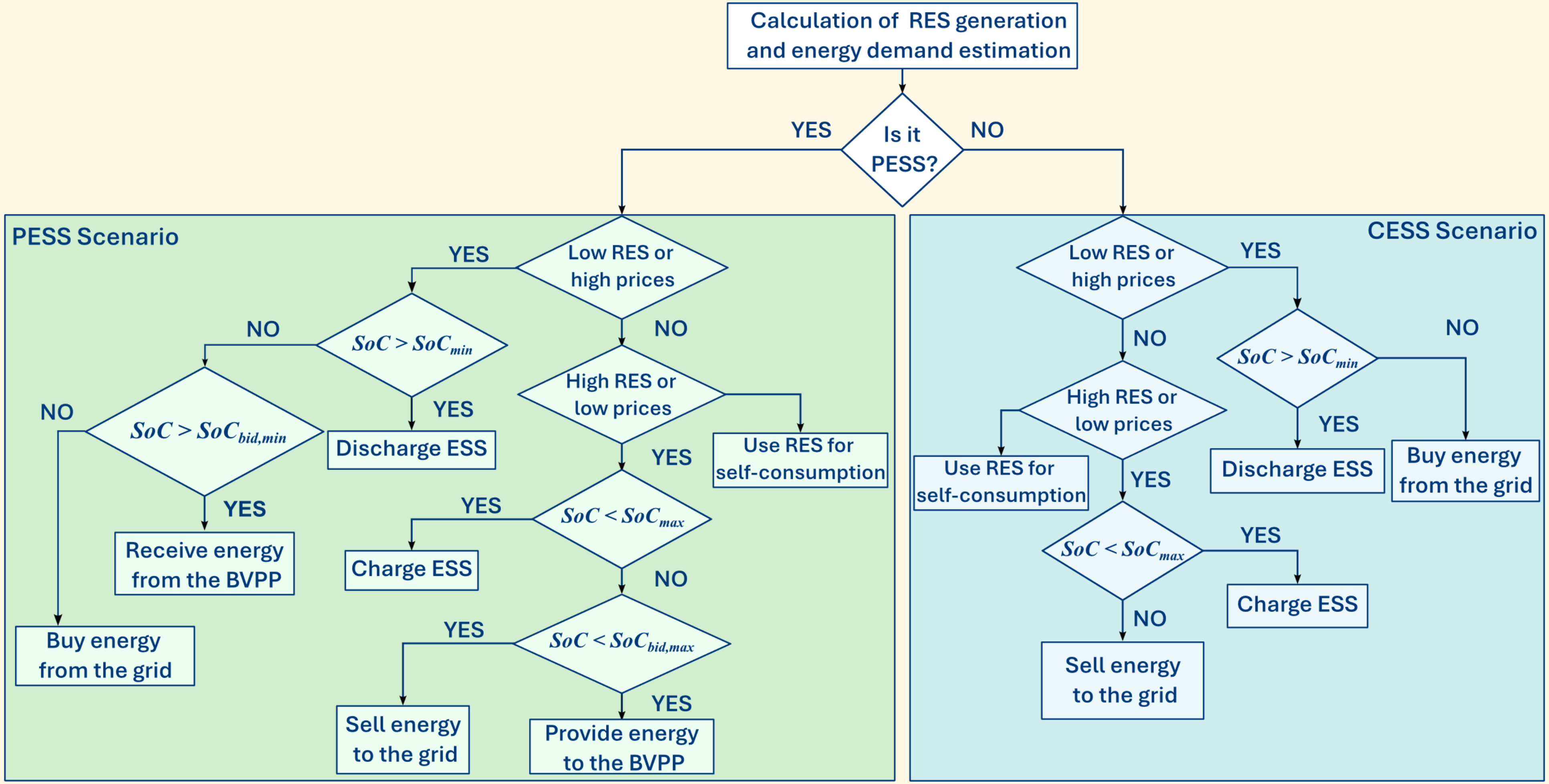
Overview of the problem



(Overview-flowchart of the BVPP-EMS control algorithm)



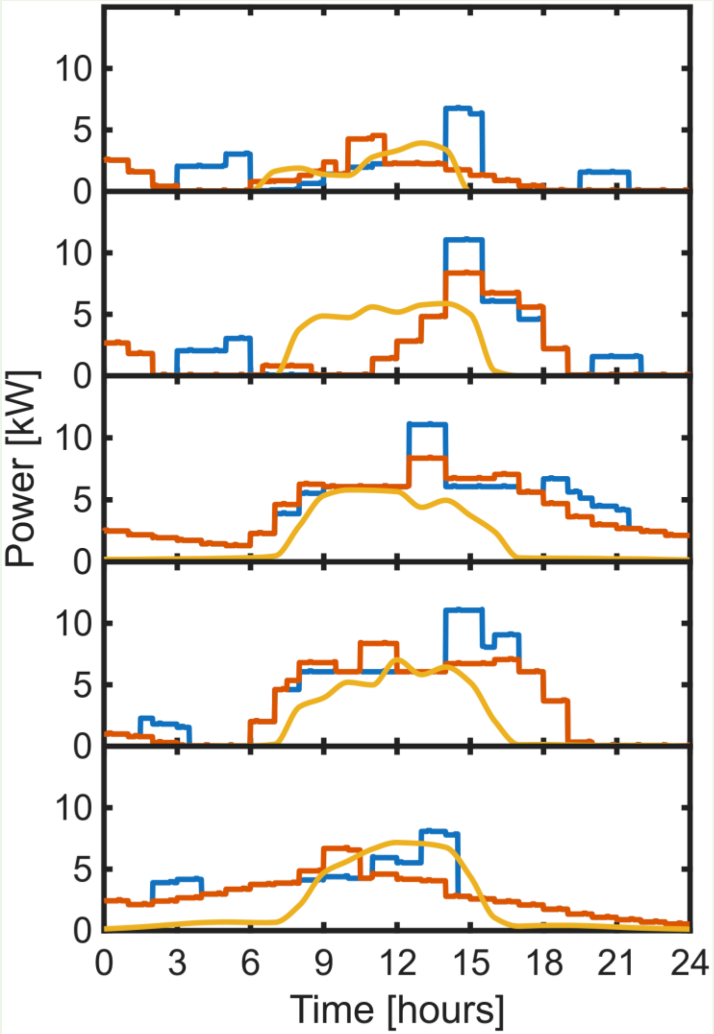
Algorithmic model of the Building Virtual Power Plant (BVPP)

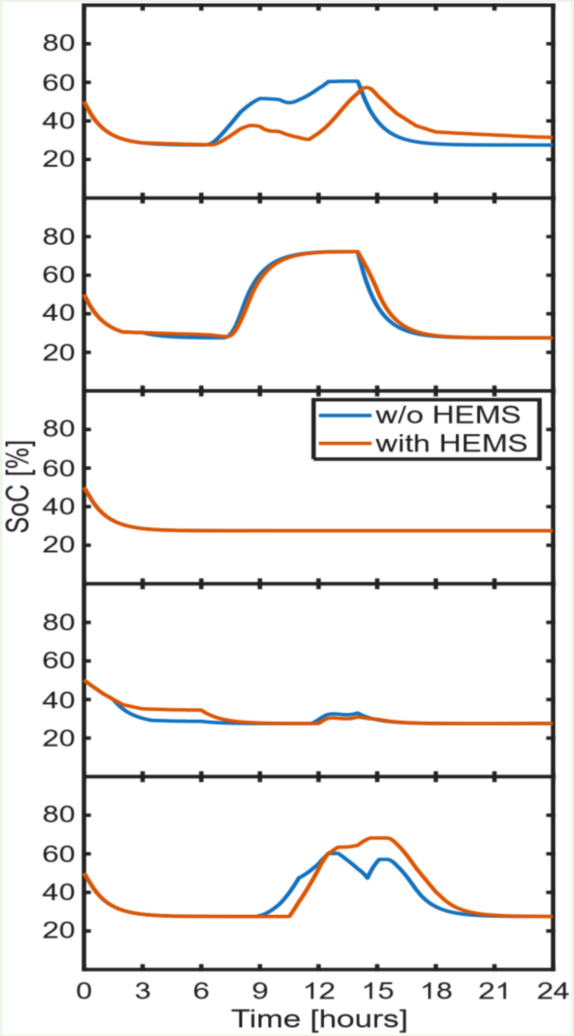


Simulation results

Average daily production and consumption data

Building	Consumption	Production
Building 1	29.45 kWh	44.00 kWh
Building 2	43.39 kWh	48.32 kWh
Building 3	32.71 kWh	63.42 kWh
Building 4	37.21 kWh	54.28 kWh
Building 5	18.39 kWh	69.65 kWh





Simulation results of 5 buildings with PESS

Simulation results

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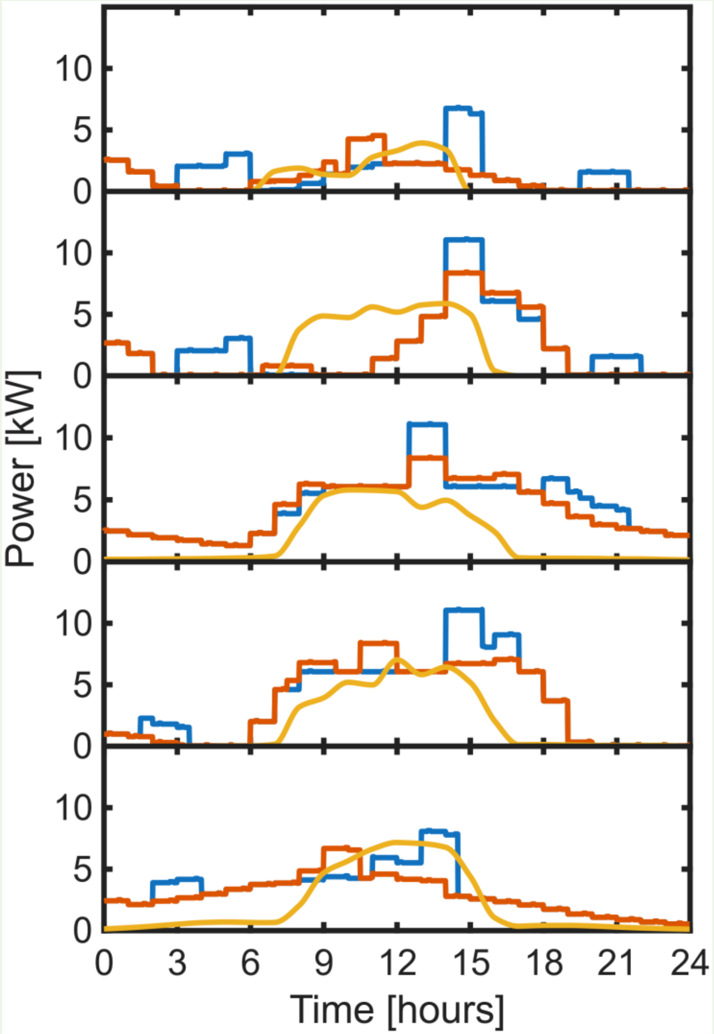
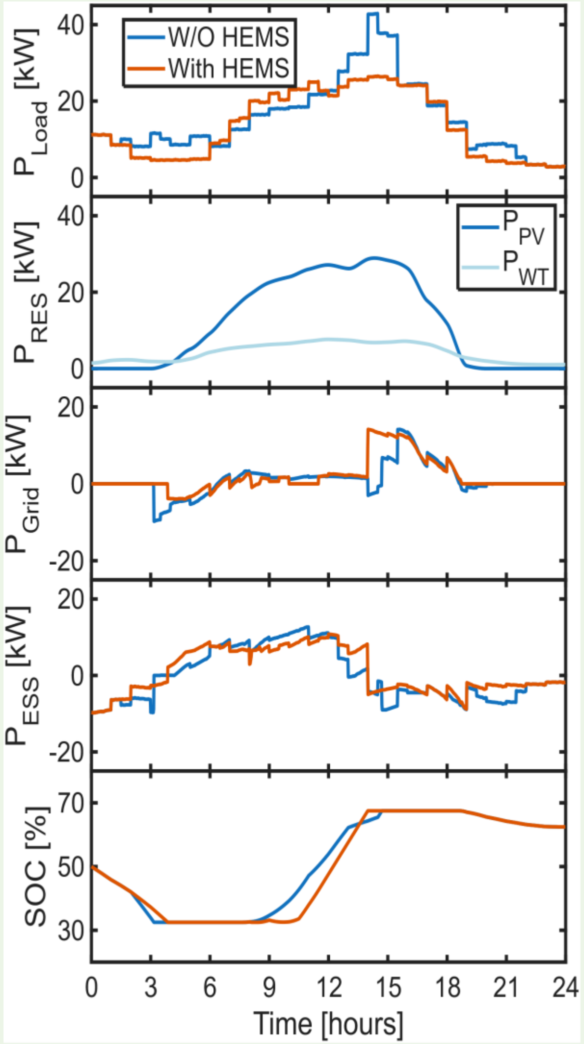
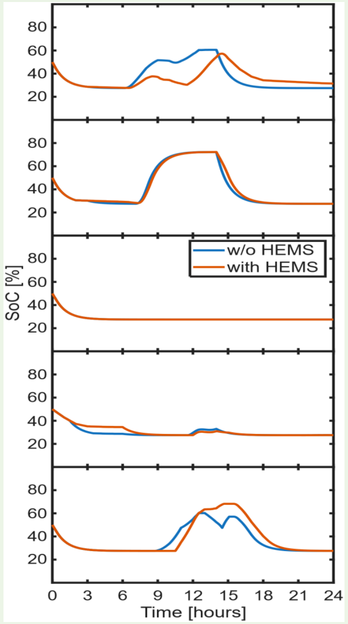


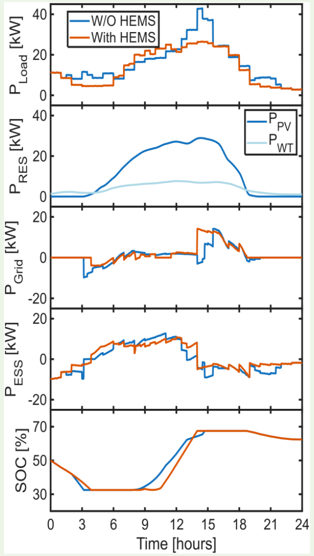


Simulation results of <u>CESS</u>

Simulation results



Simulation results of 5 buildings with PESS



Simulation results of CESS

Annual cost comparison of CESS and PESS

	With HEMS	Without HEMS
CESS	186 €	562 €
PESS	711 €	1354 €

Conclusions

- This study presents a comprehensive approach to energy management within a BVPP, leveraging distributed Renewable Energy Sources (RESs) and Energy Storage Systems (ESSs).
- Two ESS sharing frameworks (Personal ESS and Community ESS) were analyzed and compared.
- The ***CESS scenario*** (utilizing a common ESS) ***demonstrated superior economic performance*** by achieving lower grid dependency and more effective coverage of the BVPP's demand. In contrast, ***the PESS scenario, where each building owns a separate ESS, incurred higher costs due to less efficient utilization of ESS capacity***.
- In conclusion, the ***economic and operational advantages of the CESS framework, combined with advanced ESS management and HEMS***, position the BVPP as a promising approach for enhancing energy efficiency and reducing electricity costs, all while prioritizing resident comfort and sustainability.