Energy Communities: what is the impact of members’ habits on fossil fuel consumption?

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Background

Challenge of our century → To achieve a sustainable energy transition to mitigate Climate Change

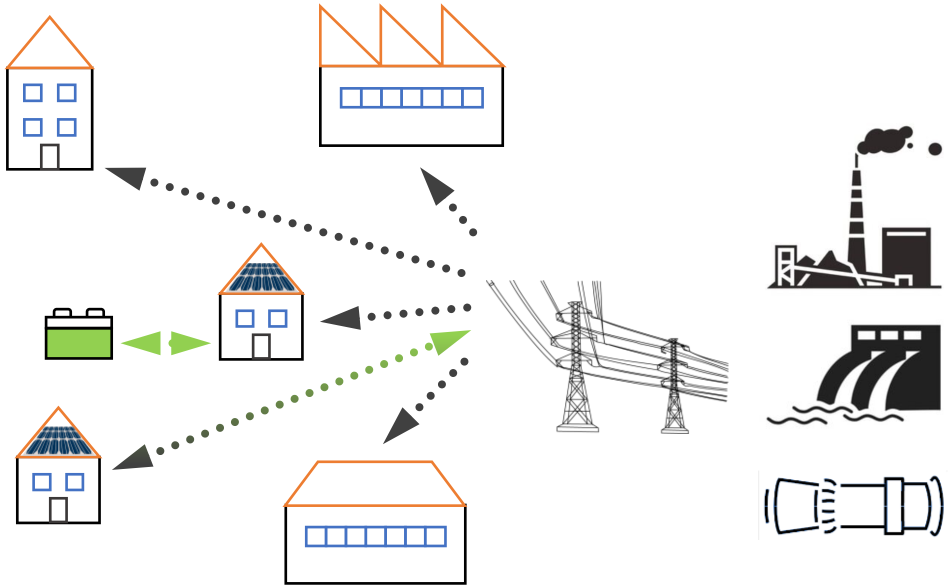
Energy Community (EC)

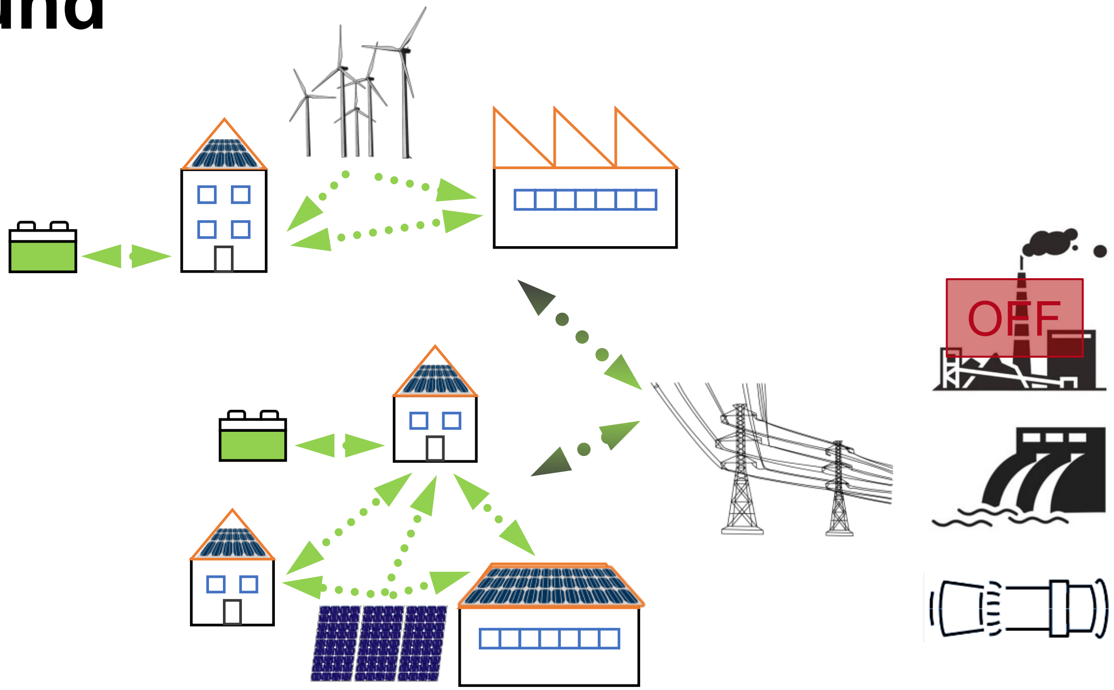
local aggregation of citizens, public entities, and private enterprises that, in synergy, organize their energy production from RES maximizing energy sharing and self-consumption to bring economic savings (in terms of reduced costs and/or incentives)

Directive EU 2018/2001
renewables self-consumer
jointly acting renewables self-consumers
renewable energy communities

DL Dec. 30, 2019, No. 162 … et seq.
renewable energy communities

Background

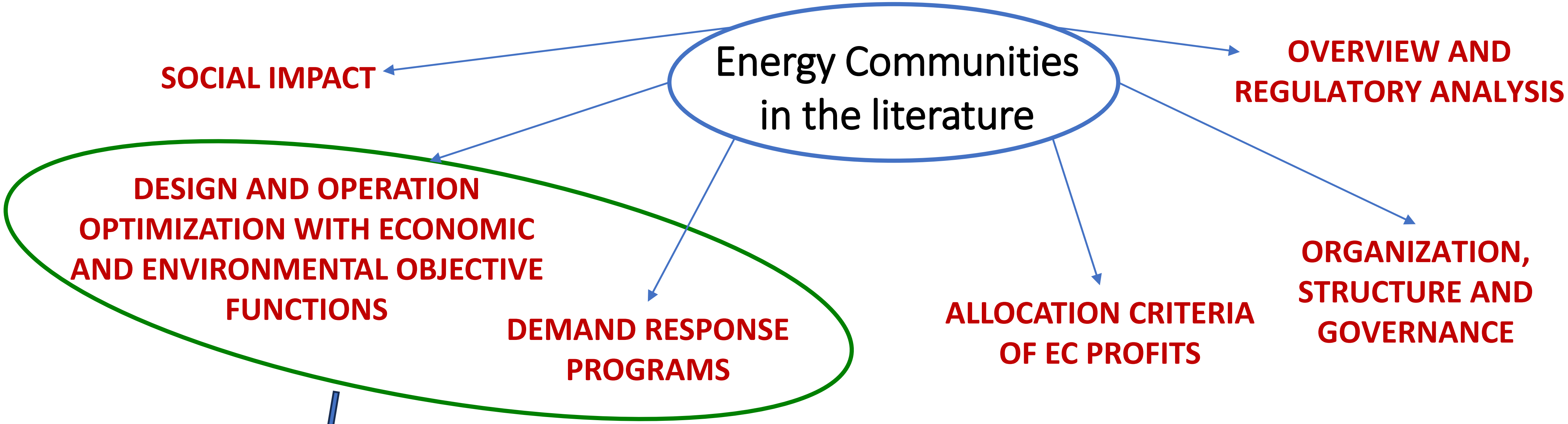




Centralized generation
&
Passive consumers +
some prosumers

ECs

Distributed generation
from RES
&
Local energy sharing

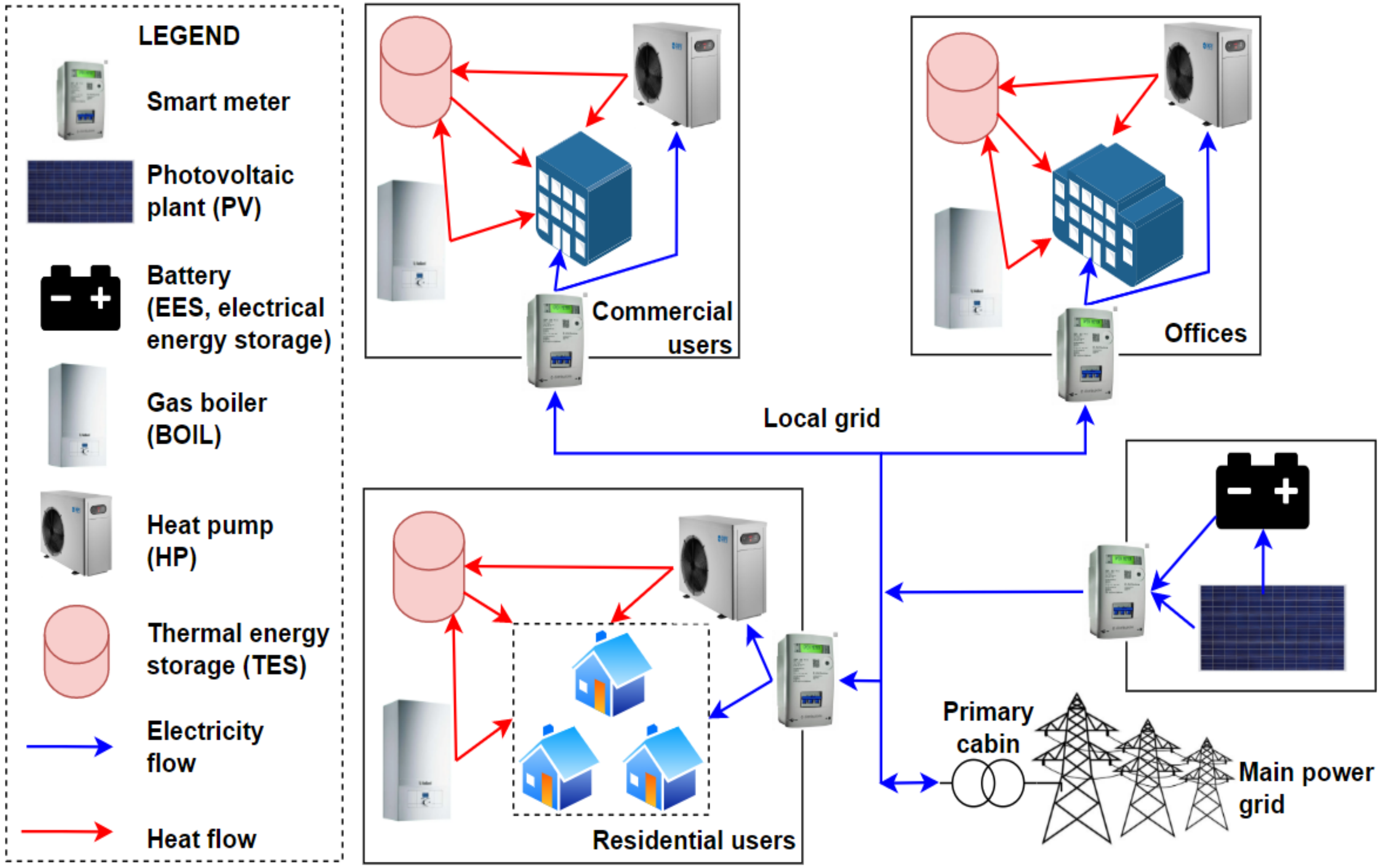


The design of the EC is usually based on the generation side, while the demand response programs are applied to an EC with a given design

Research question:

What would be the benefits if demand response is considered already at the design stage of the EC?

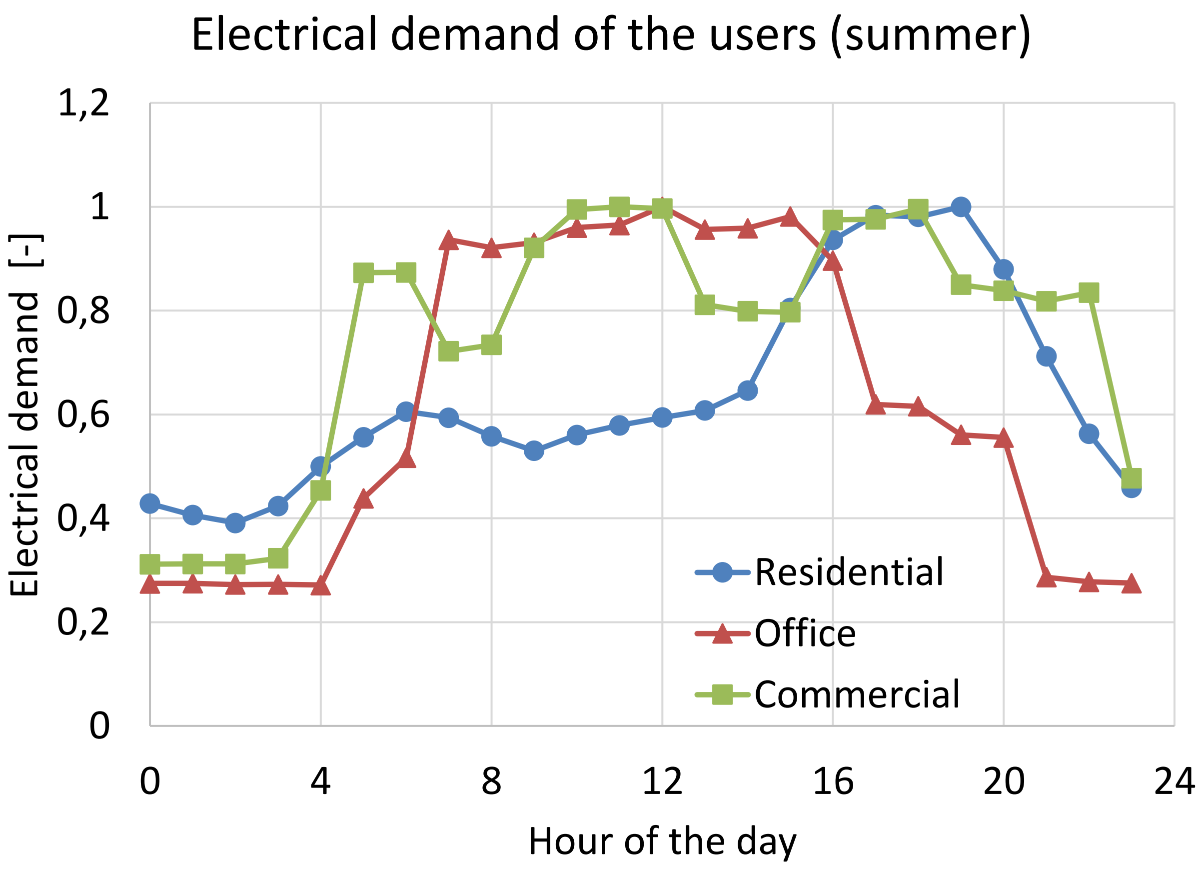
Case study



The EC is connected to the main power grid and is composed of:

- residential users, commercial users and offices;
- a photovoltaic (PV) plant possibly connected to a battery;
- boiler, heat pump and thermal energy storage that each user may install to satisfy his own thermal energy demand

Energy demands in ECs



- Variation of the share of residential, commercial and office users

  [by keeping the same yearly energy demand]

  ⇩

  Different shapes of demand profile having the same integral

- Variation of the degrees of flexibility (“DR”) of the electrical demand

  [in-between 0 - 50% of the hourly demand by keeping the same integral]

MILP optimization problem

$$\min_{\boldsymbol{x}} \quad f = f' + f'' = \left(\sum_k w_k \sum_h f'_{k,h}\right) + f'' \qquad \textbf{[COST]}$$

$$subject\ to \qquad \varphi \leq \varepsilon\varphi_0 \qquad \textbf{[}CO_2\textbf{ EMISSIONS]}$$

Other constraints:

- energy balances

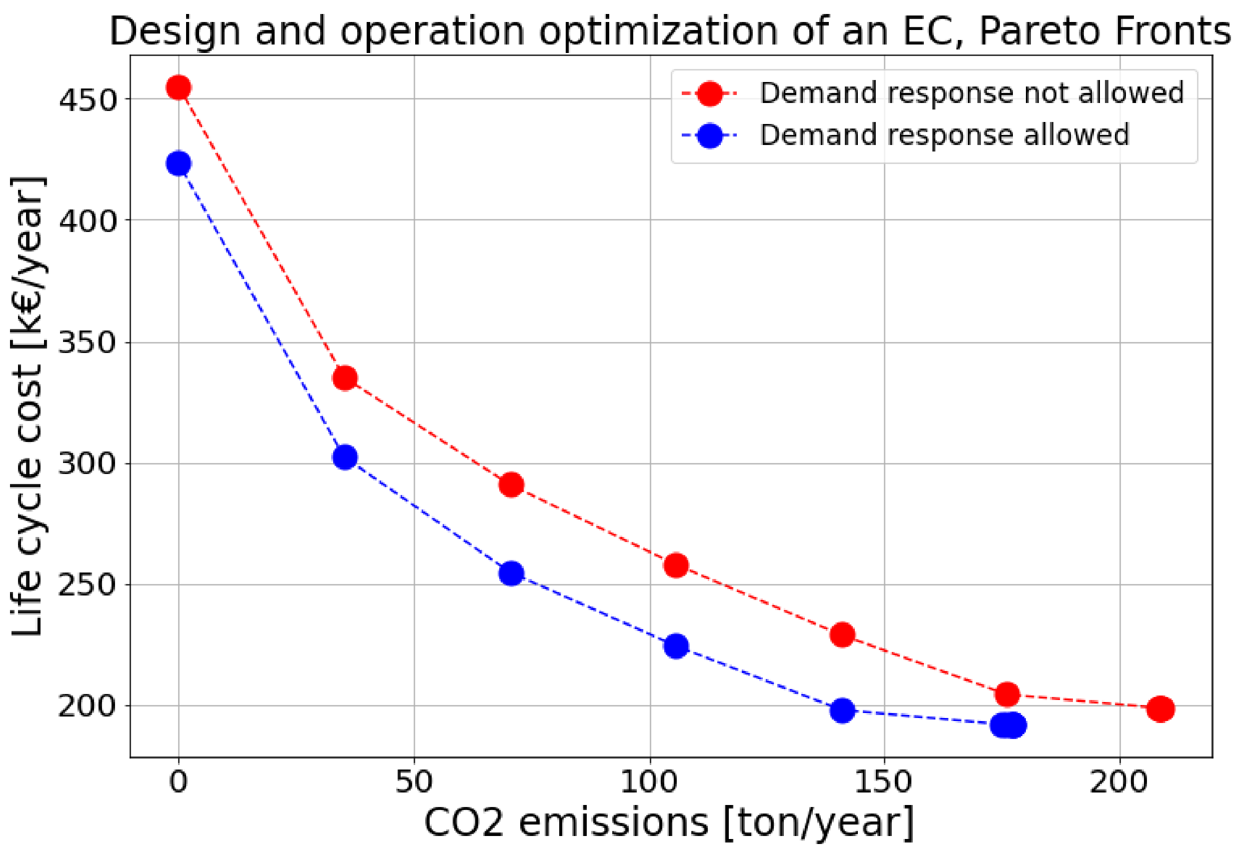
- characteristic equations of the plants

- flexibility of the energy demand while keeping the same integral

- f is the life cycle cost of the EC
- $f'_{k,h}$ is the operational cost of the time step h of the typical day k
- f'' is the investment cost
- φ represents the CO_2 emissions of EC
- φ_0 represents a reference value for the yearly CO_2 emissions

Reference case:
- The entire yearly electricity demand is met by the national grid
- The entire heating demand is fulfilled by gas boilers
- DR not allowed

Results – Pareto fronts



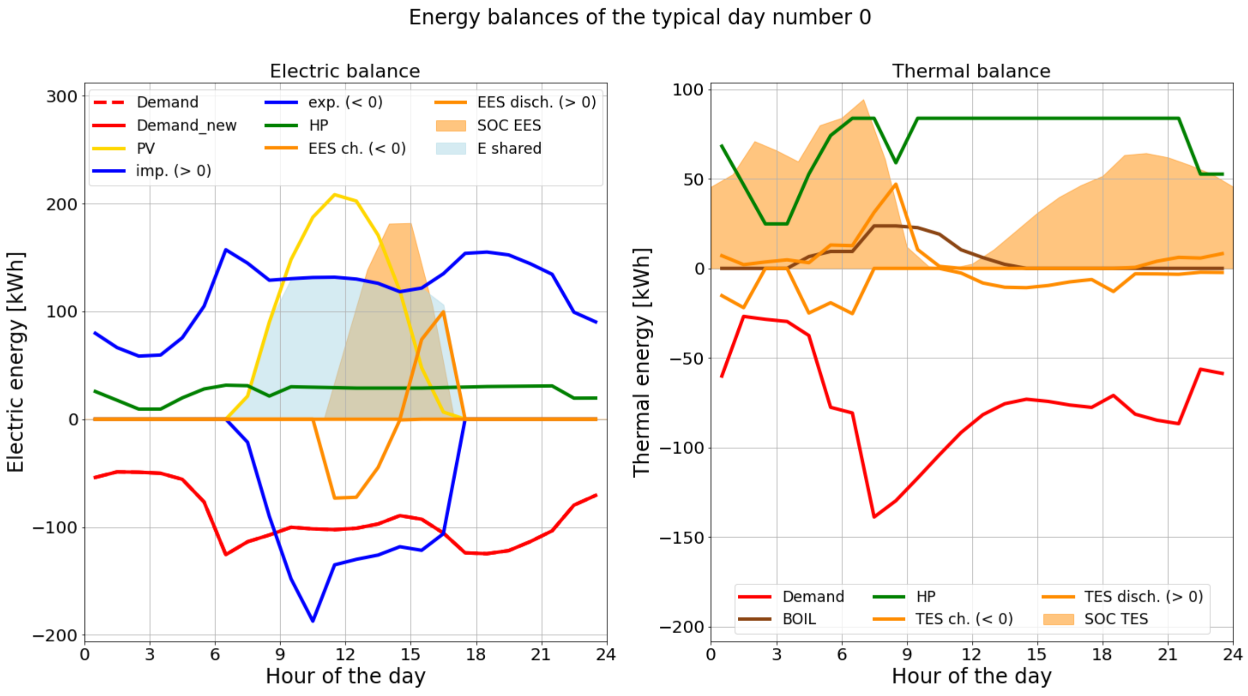
- 1/3 residential, 1/3 commercial and 1/3 office

- A reduction of 35 tCO_2/y
  - costs 5.6 k€/y from 209 t/y to 175 t/y
  - costs 120 k€/y from 35 t/y to 0 t/y

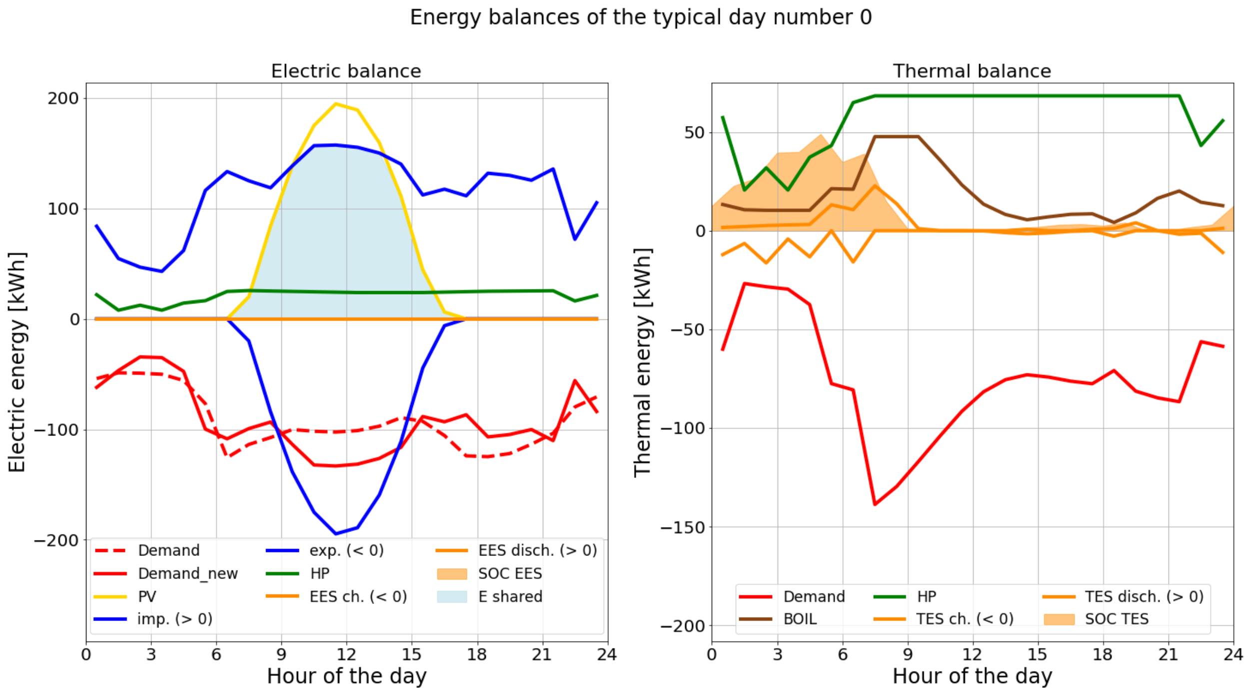
- A demand flexibility of 30% in the design of the EC (blue line) shifts the entire Pareto front towards lower costs

Results [power flows with an emission cap = 40%]

No demand flexibility



30% demand flexibility



- For the same amount of shared energy, a demand flexibility of 30% avoids the installation of 182 kWh of batteries and reduces the life cycle cost of the system by more than 13%

Results – the influence of users' share

Electrical demand met by the national grid [MWh/year]	DR=0%	DR=10%	DR=20%	DR=30%	DR=40%	DR=50%
Res=0%; **Off=100%;** Com=0%	388.71	361.04	355.35	314.51	301.43	283.35
Res=0%; Off=50%; Com=50%	434.17	406.99	387.78	358.81	325.00	297.92
Res=0%; Off=0%; Com=100%	474.68	443.58	413.32	386.44	357.94	332.73
Res=50%; Off=50%; Com=0%	476.87	448.09	415.25	383.60	353.56	325.24
Res=33%; Off=33%; Com=33%	495.08	464.26	430.79	397.32	363.76	330.10
Res=50%; Off=0%; Com=50%	520.15	492.03	459.61	432.15	393.76	366.15
Res=100%; Off=0%; Com=0%	568.33	542.34	513.11	491.81	454.11	430.26

- Increasing demand flexibility reduces both carbon emissions and the need for grid electricity.
- In the 100% residential community the electrical demand that is not covered by PV is 45 % higher than that of the EC composed of 100% offices.

Conclusions and take-home messages

Demand response

- It shifts energy consumption towards periods of higher availability of renewable energy in order to **increase the energy sharing and**, in turn, **decrease the share of energy demand that is covered by fossil fuels**
- In collective forms of energy sharing (e.g., ECs), it shows a great potential in **reducing the investment and operation costs** required **for decreasing CO_2 emissions**

➢ Users with a **demand profile having a good match with that of renewable sources** (e.g., offices) are facilitated in the decarbonization process and can achieve the same benefits of users having a worse match (e.g., residential) by modifying their demand and, therefore, their habits in a minor way

→ The climate crisis forces us to review our energy consumption and, in turn, our lifestyle. The demand response can be a way to start this process and make people aware that one of the realistic solutions to this crisis is that of consuming renewable energy when it is available.

Thank you for your attention!

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Backup Results

- 1/3 residential, 1/3 commercial and 1/3 office
- No cap on CO_2 emissions

Cases	Energy shared [MWh/y]	CO_2 emissions [ton/y]
a. Design and operation optimization of the EC (no DR)	379.4	209 ton
b. Operation optimization of the EC with DR 30% for the design from a)	+ 16 % (compared to a.)	- 10 % (compared to a.)
c. Design and operation optimization of the EC with DR 30%	+ 7 % (compared to b.)	- 7 % (compared to b.)