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ENEA
Italian National Agency for New Technologies, Energy and Sustainable Economic Development

Fondazione Eni Enrico Mattei

Towards the integration of prosumers in DH networks

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4th International Conference on Smart Energy Systems and 4th Generation District Heating 2018
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Introduction

District Heating users are usually showing **"standard" heat load profiles**, leading to a standard aggregated profile for the network.

The potential upgrade to **prosumers** (through **distributed storage** or **generation** capacity) can allow the users **changing their demand** profile thus leading to a **different aggregated load profile**.

This aspect can have **significant consequences** on the **network** and **plant operation.**

Research questions

What are the **consequences** of **final users' and prosumers' operational logics** in changing their demand pattern?

How to avoid that **variable operation logics** have **negative consequences on the operation of the network** if considering **economic** and **environmental** drivers?

Research activity

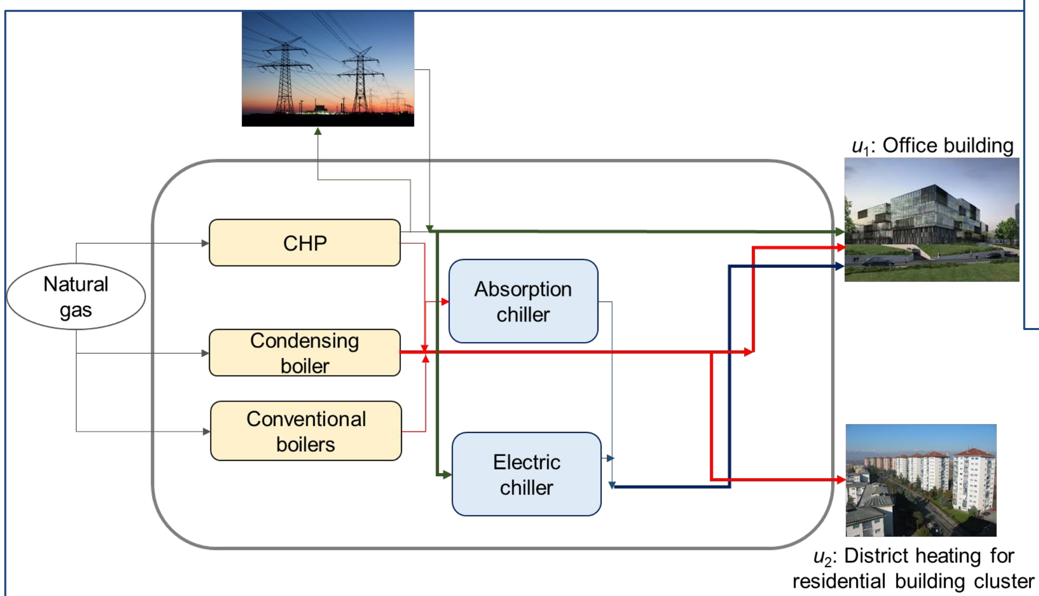
Analysis of different demand patterns in existing District Heating and Distributed Energy Systems in case of: distributed **heat storage**; **final users'** different operational logics; integration of **RES**; upgrade to **prosumers**.

Evaluation of the results from the analysis of **economic** and **environmental optimization** strategies (due to the systems operator and the finale users logics) through the use of **multi-objective optimization tool**.

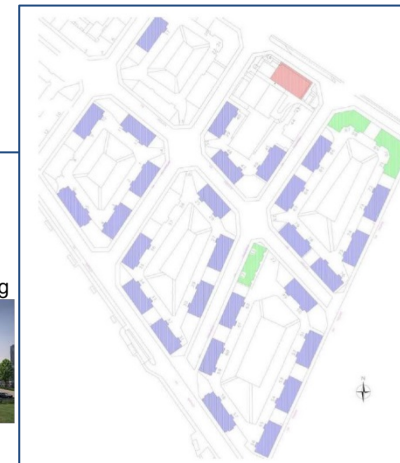
Case study

Distributed energy system (DES) in Italy:
- supply: grid, CHP, condensing boiler, two conventional boilers, (absorbtion chiller), (electric chiller)
- demand: office building, residential building cluster

Res. 240.000 m3, tert. 50.000 m3, 11.000 MWh/y demand



Scheme of the DES



Layout of the neighborhood

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Distributed storage scenarios

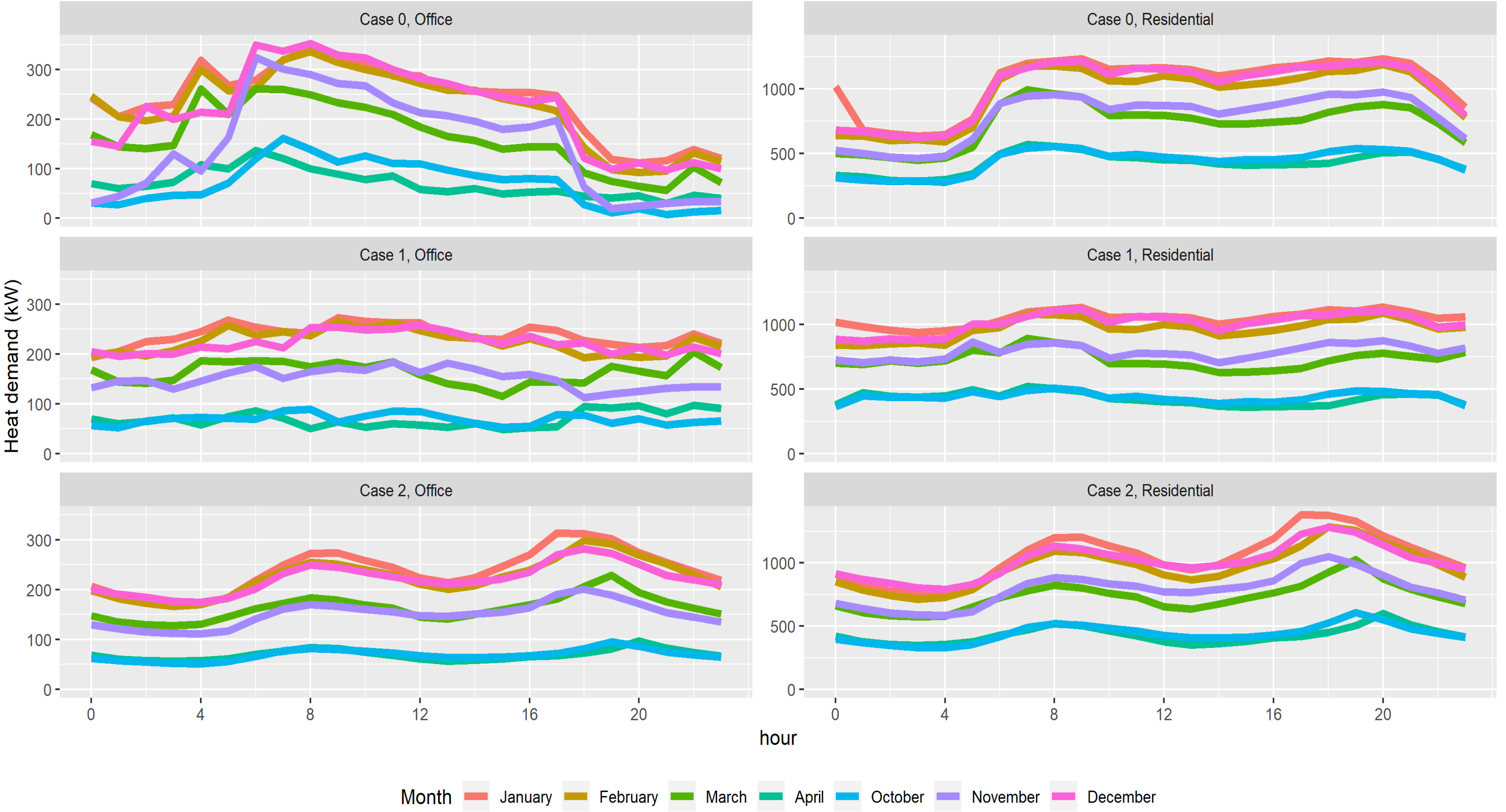
Case 0: without heat storage, current demand profile
(real data from the operator)

Case 1: with distributed heat storages, **traditional optimization** to decrease morning peaks towards a “flat profile”

Case 2: with distributed heat storages, **economic-driven optimization** towards the adaptation to CHP electricity selling prices

Case 1 and **case 2** have been obtained by **simulating** the effect of **distributed energy storage systems** on the **aggregate demand**. A single storage system has been chosen for the office (single building), and multiple systems for the residential users.

Heat load profiles



Optimization methodology

Economic and **environmental optimization** strategies in the 3 cases.

The optimization tool allows to find the **optimal operation strategies** of the DES which maximize the **DES operator's profit** while also reducing the **CO_2 emissions**.

The **optimization problem** is formulated as a multi-objective linear programming (**MOLP**) problem and is solved by using branch-and-cut.

The multi-objective approach allows to identify different trade-off points on the Pareto frontier, thereby offering **several operation solutions to the DES operator** according to his **economic/environmental priority**.

Optimization methodology

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- The **economic objective** is to maximize the total annual operator profit:

$$Prof = R^{Sell,grid} + R^{Sell,users} + R^{WC} - C^{Energy}$$

  - $R^{Sell,grid}$: Revenue for selling the electricity provided by the CHP back to the grid
  - $R^{Sell,users}$: Revenue for selling thermal energy to the DH users
  - R^{WC}: Revenue related to white certificates incentive scheme
  - C^{Energy}: Energy cost for buying electricity from the grid and gas for the CHP and boilers

- The **environmental objective** is to minimize the total annual net CO_2 emissions:

$$Env = CO_2^{Oper} - CO_2^{Avoid}$$

  - CO_2^{Oper}: emissions related to the electricity taken from the grid and the gas consumed by the CHP and boilers
  - CO_2^{Avoid}: emissions related to the electricity sold back to the grid

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Optimization methodology

The **problem constraints** are:

- Operation constraints for technologies (capacity constraints, ramp-rate constraint for CHP)
- Operation constraint for the DH network (capacity constraint)
- Energy balances (electricity and thermal energy balances)

To solve the **multi-objective optimization problem**, the weighted-sum method is used:

$$FO = c\omega(-Prof) + (1-\omega)Env$$

- *c* is a scaling factor allowing *c*(-*Prof*) and *Env* have the same order of magnitude
- By varying the weight *ω* in the interval 0–1, the economic/environmental trade-off solutions can be found on the Pareto frontier (*ω*=1→Economic optimization, *ω*=0→Environmental optimization)

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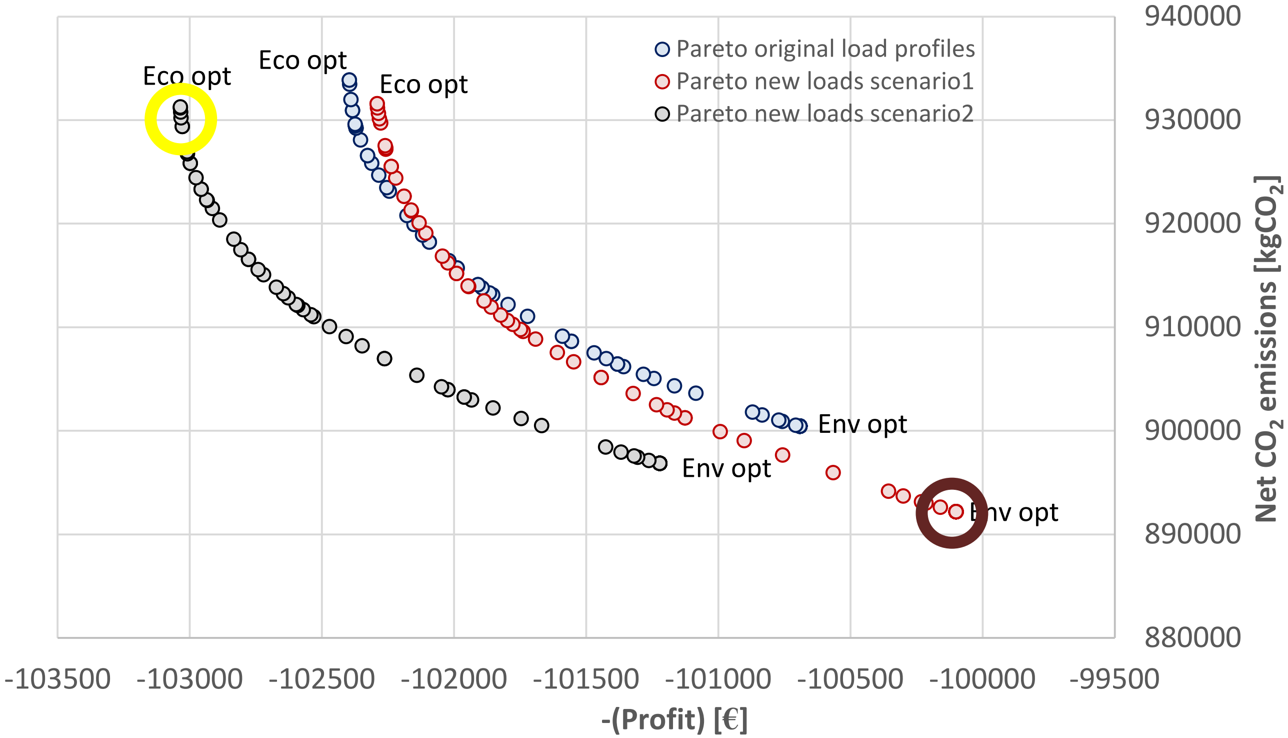
Optimization results



Pareto frontiers obtained for the 3 cases (1 year)

Case 1: Best case for the CO_2 emissions

Case 2: Best case for the operator's profit

Case 0				Case 1				Case 2			
Eco opt		Env opt		Eco opt		Env opt		Eco opt		Env opt	
Prof (€)	*Net CO_2 (ton)*	*Prof (€)*	*Net CO_2 (ton)*	*Prof (€)*	*Net CO_2 (ton)*	***Prof (€)***	***Net CO_2 (ton)***	***Prof (€)***	***Net CO_2 (ton)***	*Prof (€)*	*Net CO_2 (ton)*
102394	933.45	100691	900.43	102285	930.64	**100100**	**892.19**	**103034**	**930.20**	101221	896.84

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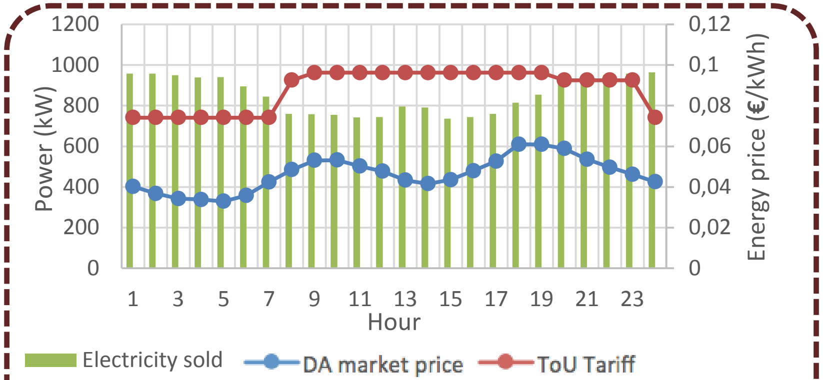
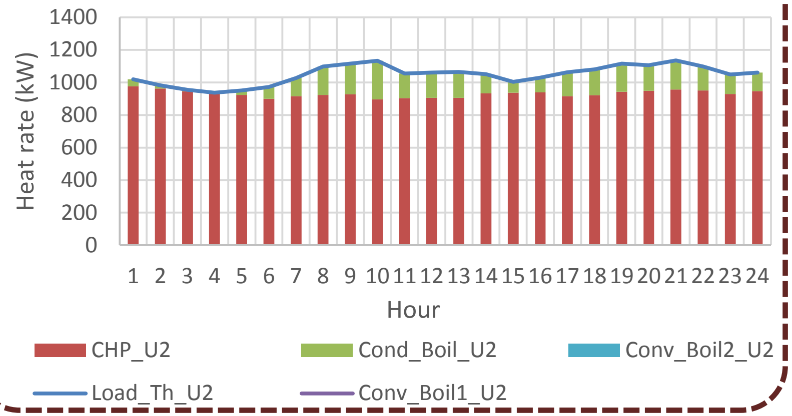
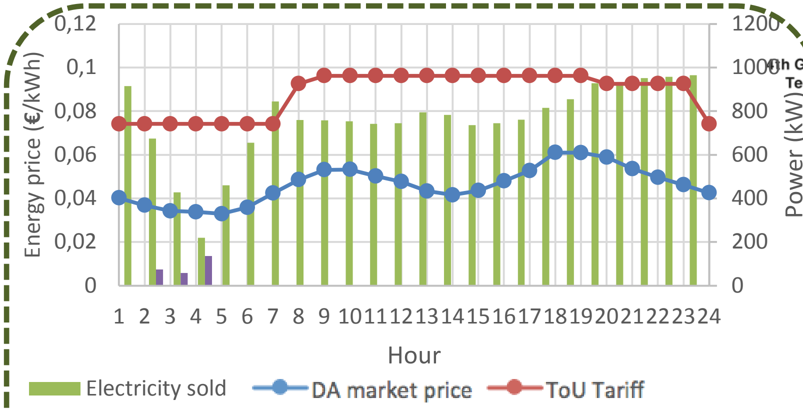
Optimization results

Optimal operation strategies for electricity in a representative day of January

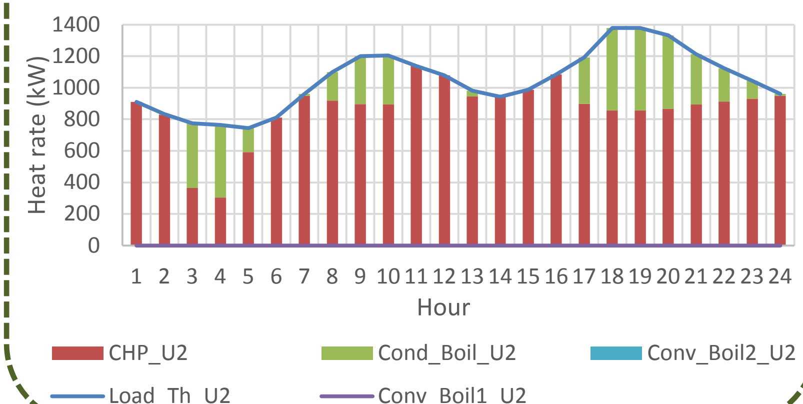


Environmental opt for Case 1





Economic opt for Case 2



Thermal energy balance for the DH users in a representative day of January

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Discussion

Final users can have different effects on the aggregated load of the network depending on their **operation logic**.
The results depend on many the characteristics of: the **grid**, the **energy units** and **sources/fuels**, the **site**, the served **buildings**, the **users' behaviour**, etc.

An **optimization model** (implemented by using IBM ILOG CPLEX Optimization Studio Version 12.6) was coupled with **different demand profiles**
→ the model can be used to evaluate the effect of different DES operation logics (both by the final users/prosumers and the DES operator) and to find the optimized operation strategies.

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Discussion

In the case study analysed (small DH + distributed heat storages) the **targets** for the **economic** and **environmental optimization strategies** are not concurrent but the optimal profiles for cases 1 and 2 **do not show significant differences** from the case 0 (without heat storages).

Case 0		Case 2	
Eco opt		Eco opt	
Prof (€)	*Net CO_2 (ton)*	***Prof (€)***	*Net CO_2 (ton)*
102394	933.45	**103034**	930.20

Case 0		Case 1	
Env opt		Env opt	
Prof (€)	***Net CO_2 (ton)***	*Prof (€)*	***Net CO_2 (ton)***
100691	**900.43**	100100	**892.19**

The DES under examination is small and does not include different technologies and RES → the effect of optimized strategies and of the use of distributed storage units is not significant.

Ongoing activities

Starting from the real data from the case study presented, we are going to model a system including solar heating and different users' operation logics for the thermal storages.
A further step will be to apply the model to analyse the effect of including distributed energy systems and prosumers.

The results are expected to give useful results for the definition of regulations that could play an **important role** to avoid low-cost- and high-emission driven operation logics.

Thank you for your attention!

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