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DEPARTMENT OF INDUSTRIAL ENGINEERING

PhD Course in Mechanics and Advanced Engineering Sciences (DIMSAI)

YEARLY PHD STUDENT REPORT - AY *2016/2017*

Curriculum number *2*

Cycle *30°*

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Supervisor: *Francesco Melino*

OPTIMIZATION STRATEGIES FOR COMPLEX ENERGY NETWORKS WITHIN DISTRIBUTED GENERATION

IL PRESENTE MATERIALE È RISERVATO AL PERSONALE DELL'UNIVERSITÀ DI BOLOGNA E NON PUÒ ESSERE UTILIZZATO AI TERMINI DI LEGGE DA ALTRE PERSONE O PER FINI NON ISTITUZIONALI

Research activities

- **District Heating Networks**
  - ✓ Design
  - ✓ Analysis

- **Smart District Heating**
  - ✓ Bidirectional heat exchange – definition of different schemes for users substations
  - ✓ Implementation of defined schemes in internal-developed tool
  - ✓ Applications: analysis of network's effects and conversion hypothesis for an existing traditional substation

- **Complex Energy Networks**
  - ✓ Thermal, electrical and cooling demand evaluation
  - ✓ Distributed and/or centralized generation systems, fossil fuel and/or renewable sources

- **Optimization of Complex Energy Networks**
  - ✓ Software EGO (genetic algorithms): scheduling optimization
  - ✓ Applications: isolated grids (particular case study: ship), small-medium existing grids (case study of Corticella)
  - ✓ MILP based approach comparison – external period at EPFL (Switzerland)

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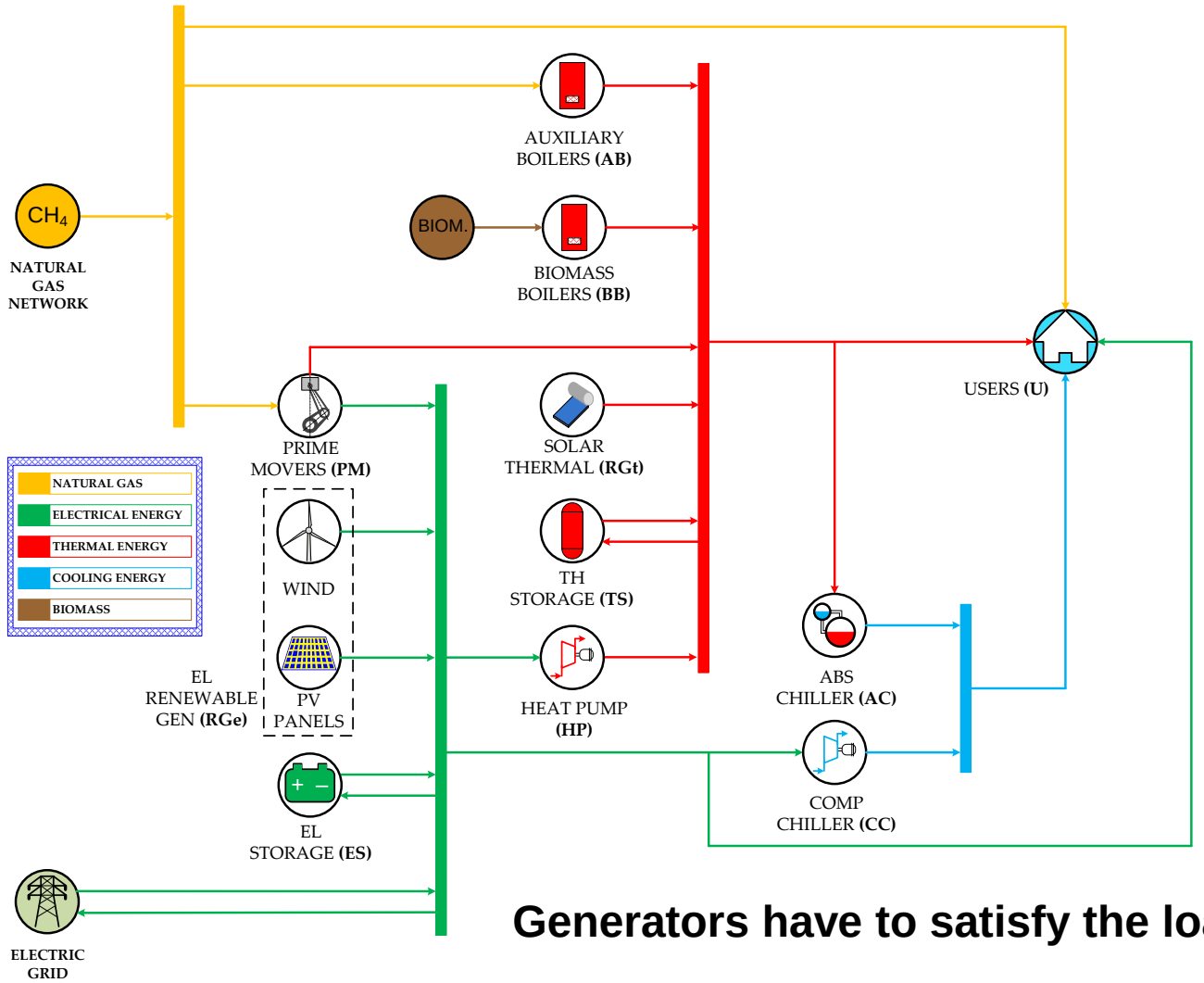
Complex Energy Networks



- Users (residential, industrial, service sectors)
- Prime movers (PM, including CHP units)
- Renewable sources
- Energy storage devices
- Thermal energy generators (AB, HP)
- Cooling machines (CC, AC)
- Electrical Grid Connection
- District Heating Network
- Natural Gas Grid Connection

Generators have to satisfy the load required by the users

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Software EGO (Energy Grid Optimizer)

- able to identify an optimal load distribution of a number of energy systems with the aim to **minimize the total cost of energy production**. It allows to optimize the managing of power generation.

$$FF = C_\lambda + C_M + C_E + C_F$$

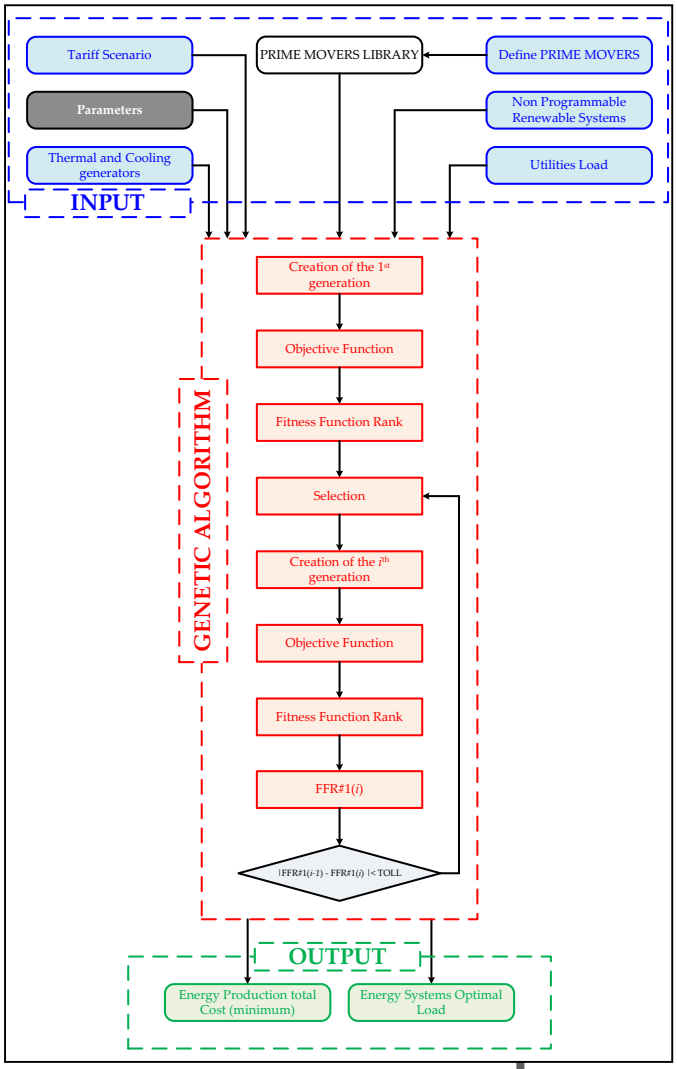
C_λ: fuel cost

C_M : operation and maintenance cost

C_E : cost of electricity

C_F : fictitious costs

- EGO is based on **genetic algorithms** (GA) and the crossover method (or recombination method) without mutation is applied in order to generate two new individuals from two parent individuals. The selection of the parent individuals is realized with a roulette method.



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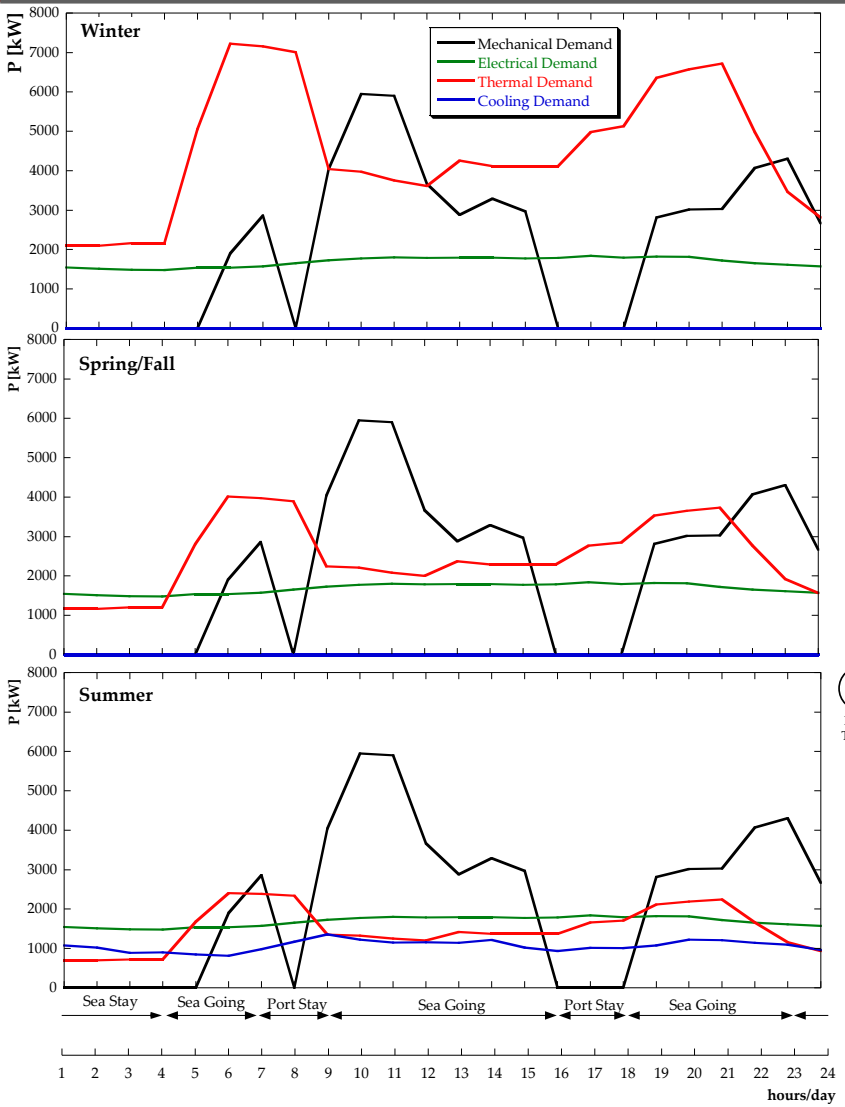
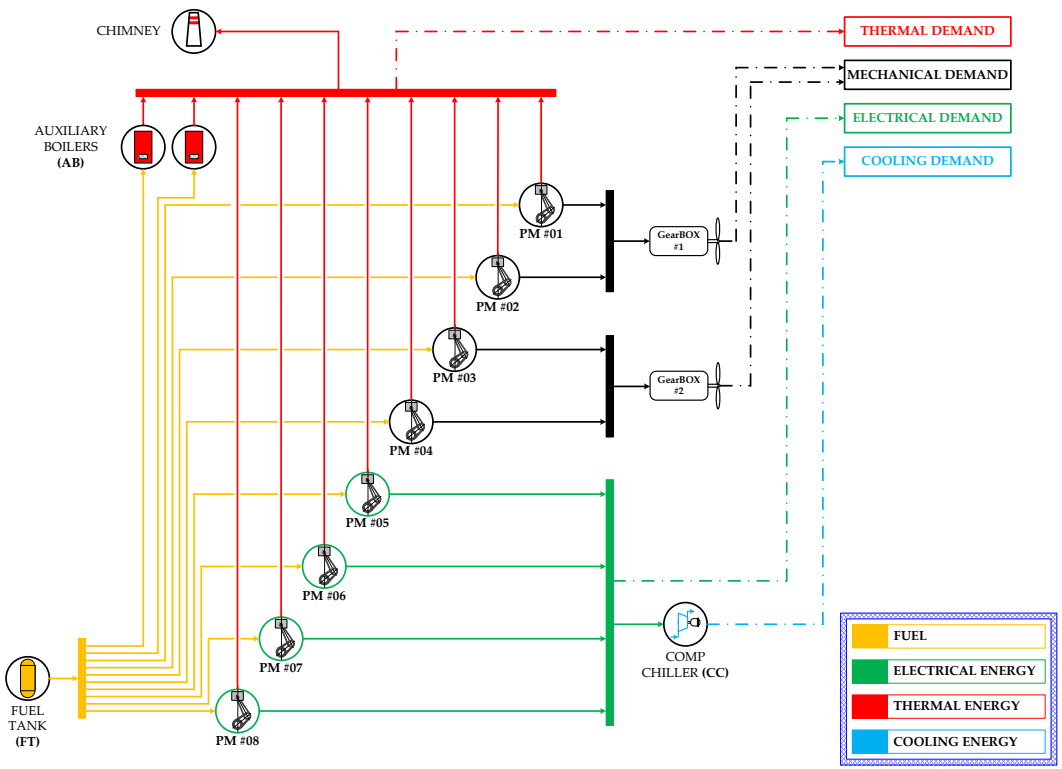
Case Study I – isolated grid: SHIP





Reference Case:

- 4 engines for mechanical demand and heat recover
- 4 engines for electrical production and heat recover
- 2 auxiliary boilers for heat production

Mechanical and electrical powers satisfied by equally sharing the production among the corresponding engines

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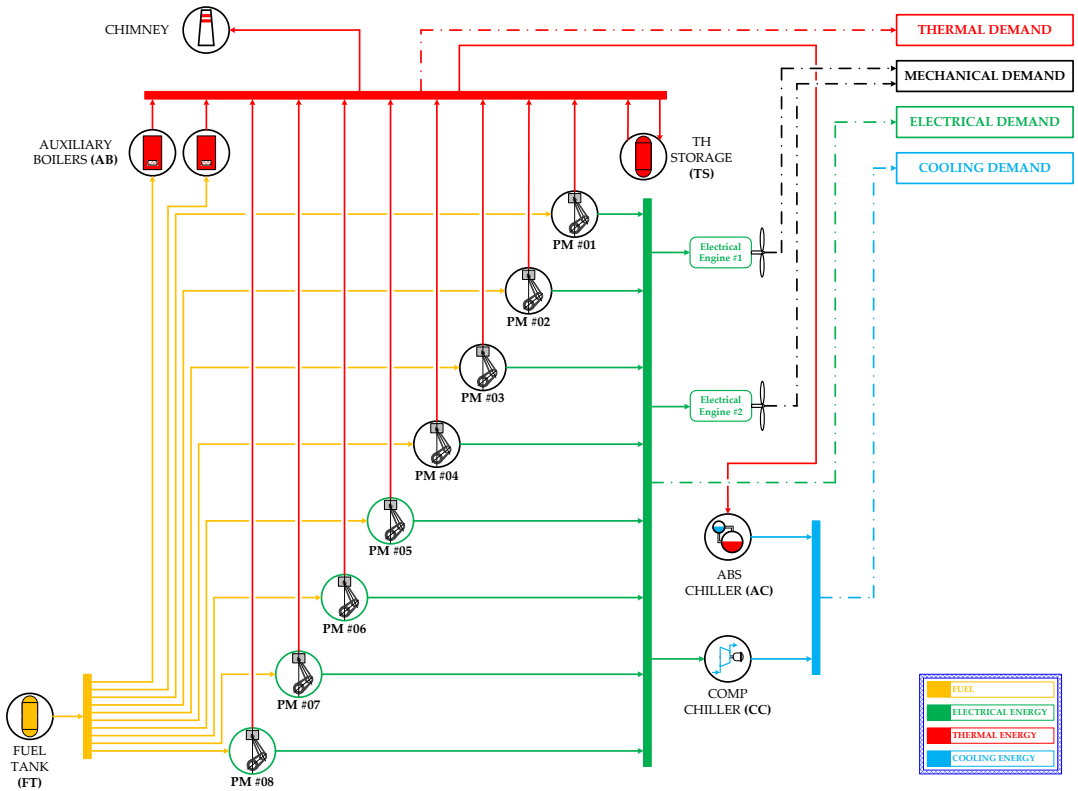
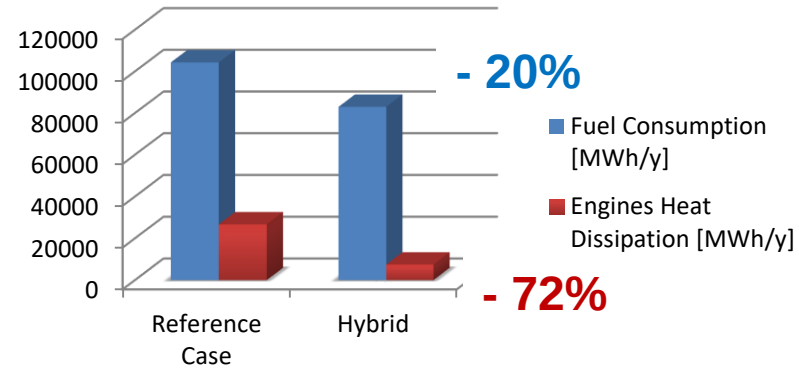
Case Study I – isolated grid: SHIP

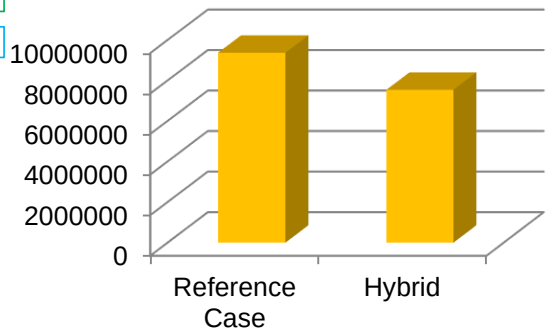
Hybrid configuration with storage and absorber chiller (HY-S-AC):

all the engines produce electrical power and the propulsion is realized by means of two electrical engines instead of the two gearboxes



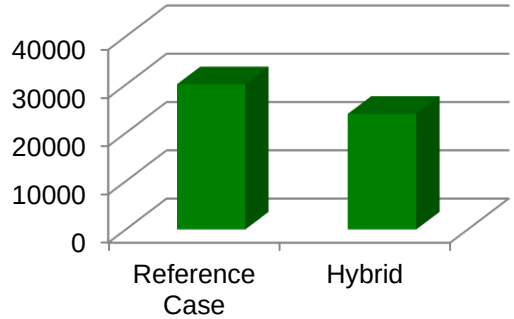
Obtained results:





Variable Costs [€/y]

- 19.5%



CO_2 Emissions [tons/y]

- 20%

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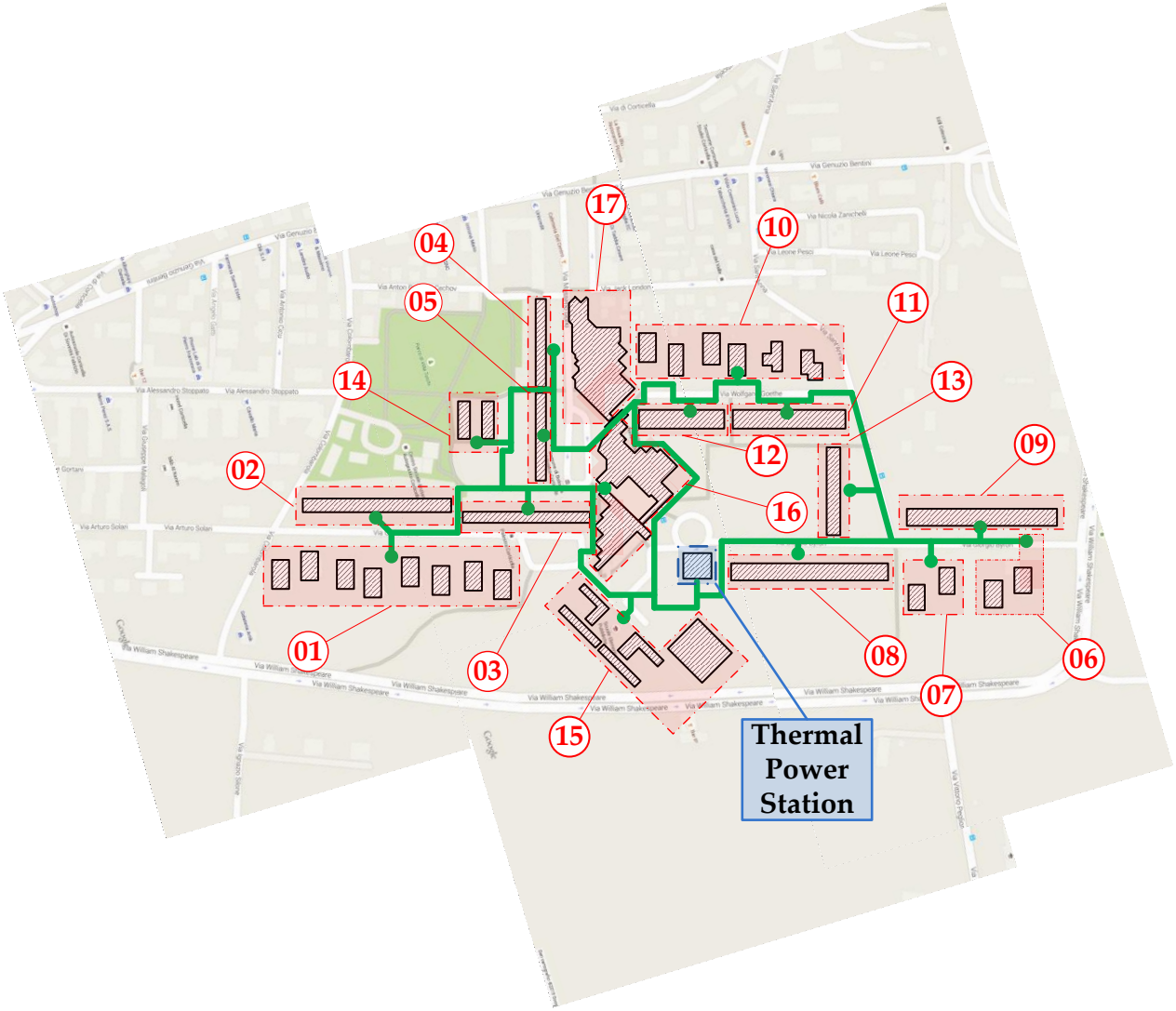
Case Study II – Connected grid: small-medium size DHN



- Location: Bologna (North of Italy)
- **17 thermal users** (13 domestic, 2 schools, 1 day-hospital and 1 super-market)
- Centralized thermal production
- DHN length: 4 km (feed + return lines)
- **Space heating and hot water** needs provided for each user, except for the super-market (only space heating is needed)

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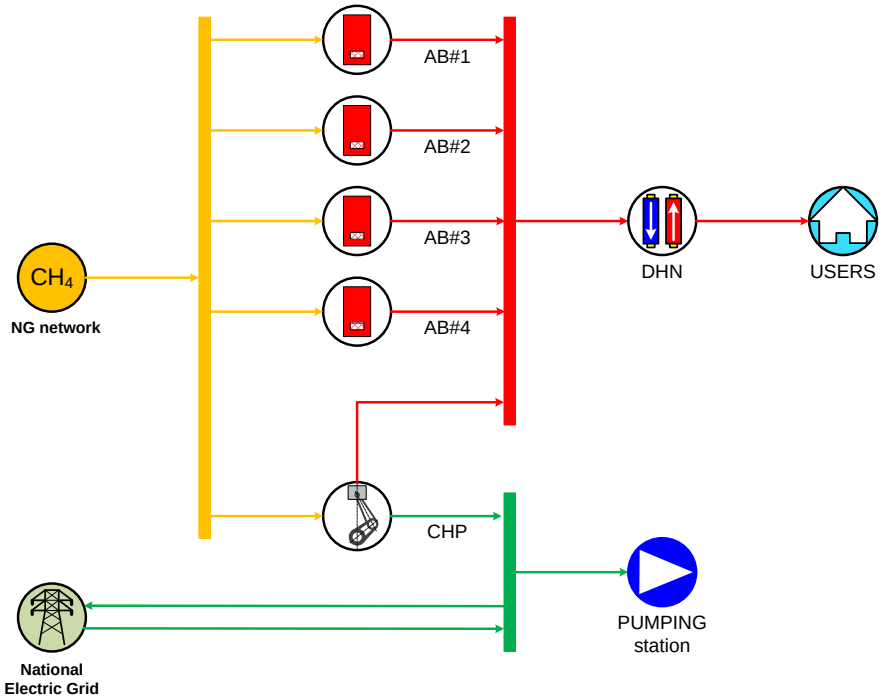
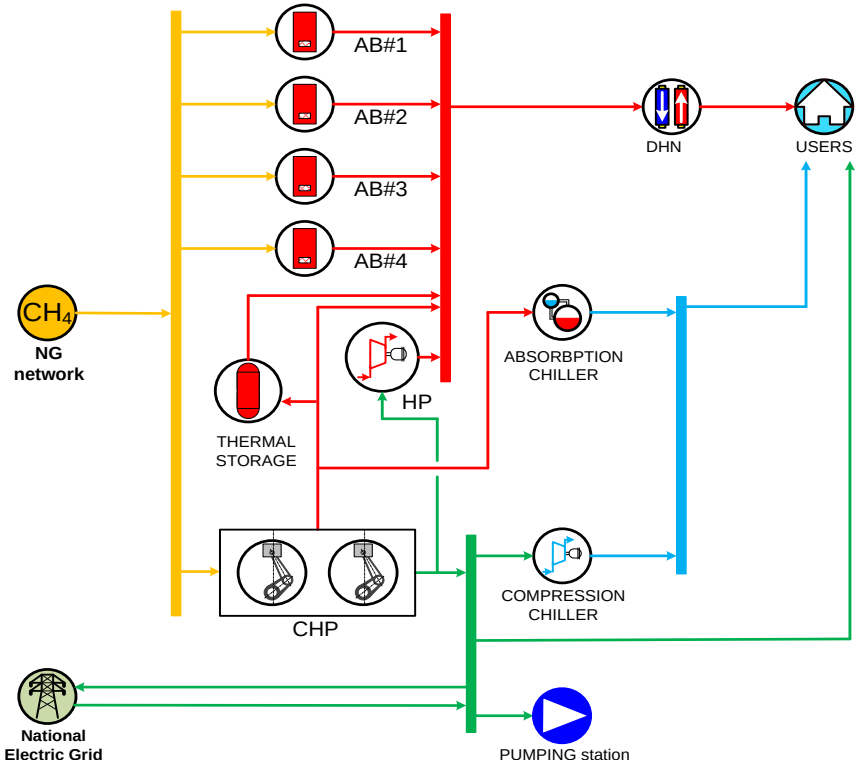
Case Study II – Connected grid: small-medium size DHN

Reference Case



- 1 internal combustion engine as CHP unit
- 4 auxiliary boilers (AB)
- Thermal production for users need (district heating)
- Electrical production for the plant pumping station only

New Configuration hypothesis



- 2 internal combustion engine as CHP unit
- 4 auxiliary boilers (AB)
- Thermal storage
- Heat pump (HP)
- Thermal production for users need (district heating)
- Electrical production for plant pumping station and user needs
- Compression and absorption chillers for user cooling needs

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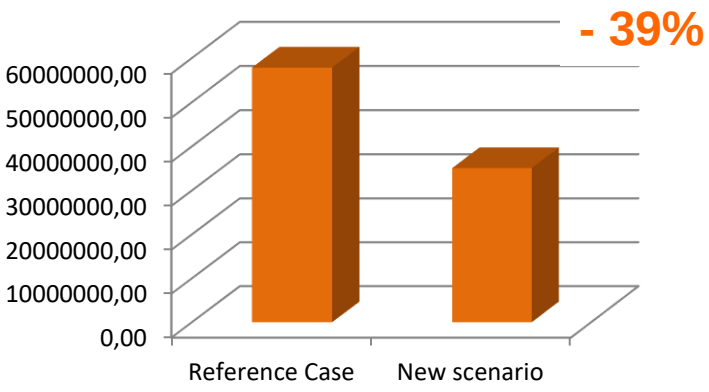
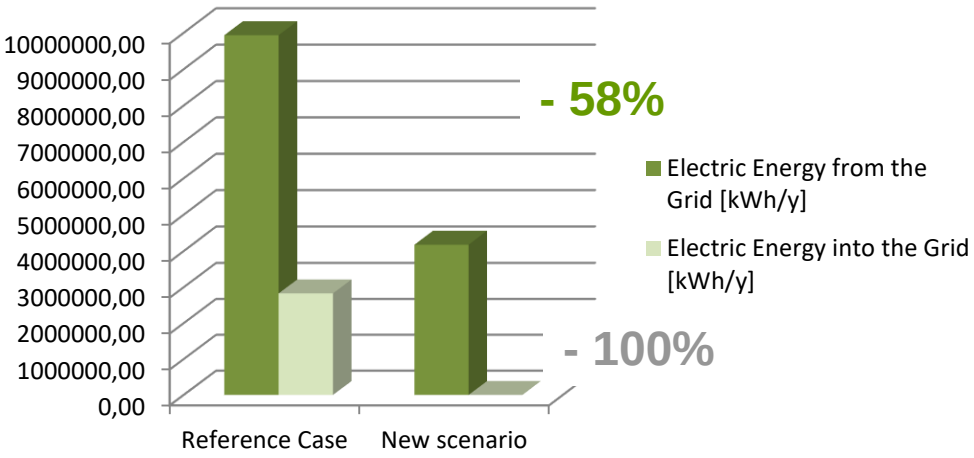
Case Study II – Connected grid: small-medium size DHN

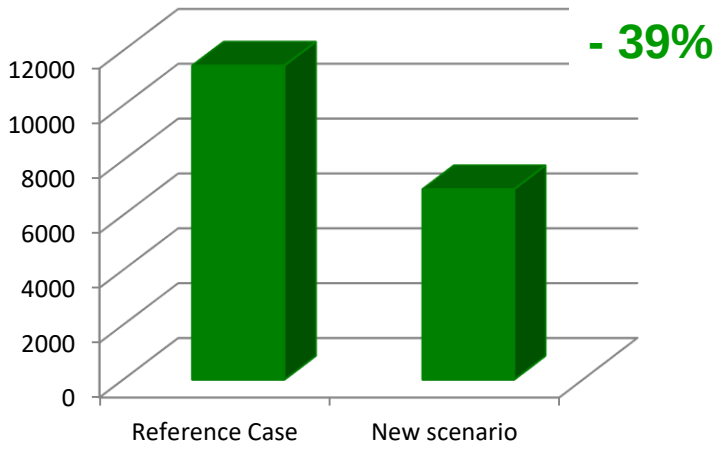
Total fuel consumption (for heat and electricity production)



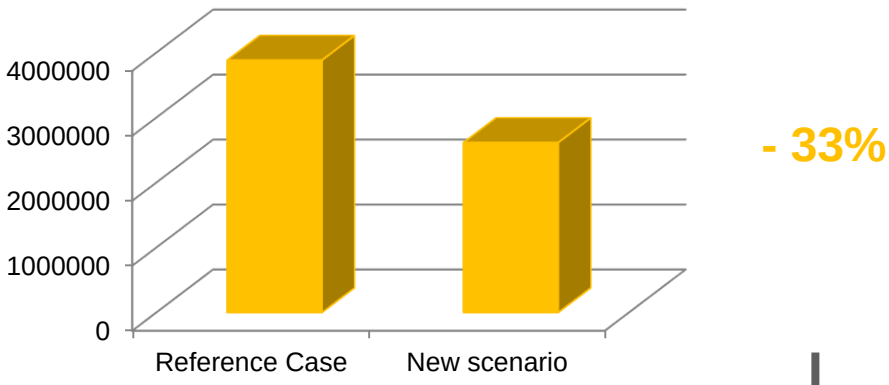
Electricity Grid



CO_2 Emissions [tons/y]



Total costs of energy production [€/y]



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Thank you for the attention

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