Associazione Italiana delle Macchine a fluido e dei Sistemi per l'Energia e l'Ambiente

Mini Grid Day Sapienza University Rome
21st of June 2018

University of Bologna

Fluid Machines and Energy Systems Research Group
Department of Industrial Engineering

Prof. Antonio Peretto and **Prof. Michele Bianchi** – Full Professors

Prof. Andrea De Pascale, Prof. Francesco Melino – Associate Professors

Ing. Lisa Branchini – Assistant Professor

Ing. Maria Alessandra Ancona – Post Doctoral Research Fellow

Ing. Saverio Ottaviano, Ing. Jessica Rosati – PhD Students

Ing. Alessandro Brilloni, Ing. Francesco Catena, Ing. Luigi Scarponi, Ing. Noemi Torricelli – Research Fellows

SPEAKER:

Maria Alessandra Ancona – Post Doctoral Research Fellow

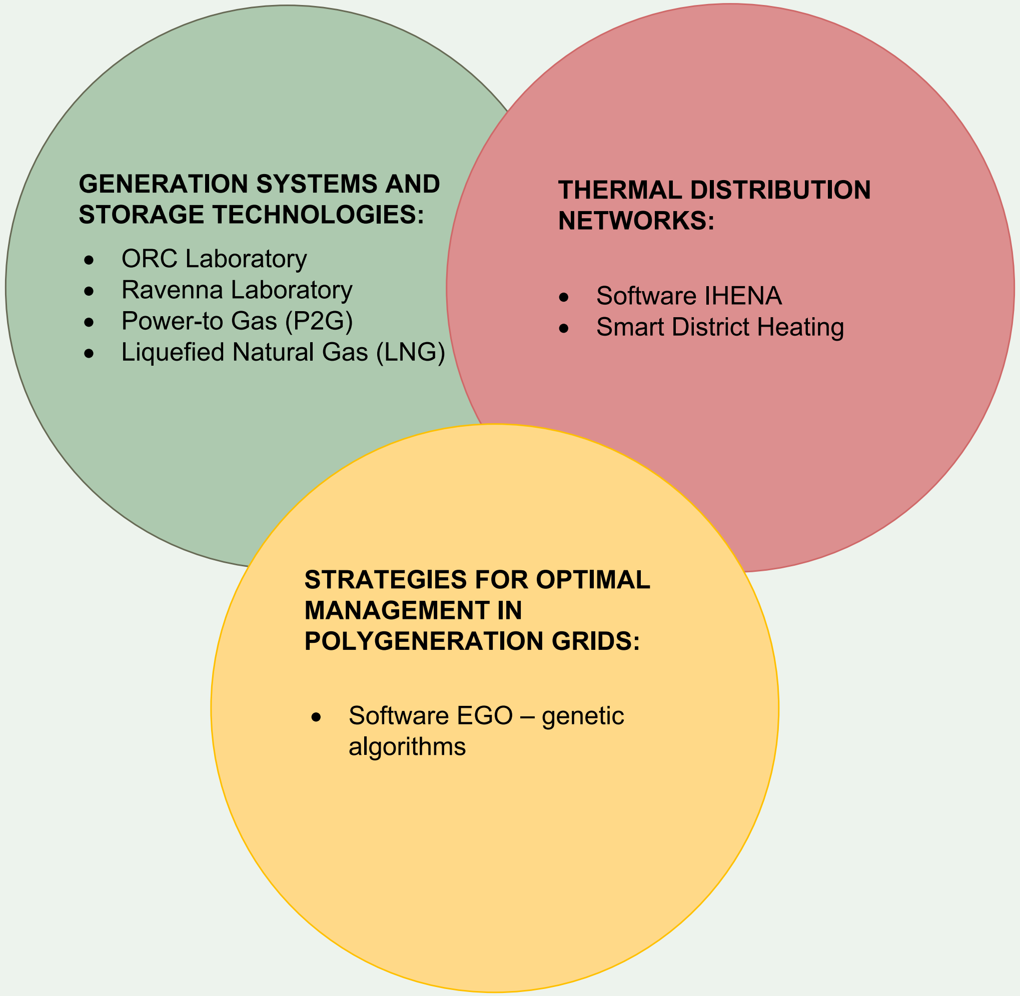
Department of Industrial Engineering (DIN)

RESEARCH TOPIC: COMPLEX ENERGY NETWORKS

Partners for Mini Grid Topics:

- Chalmers University – Göteborg (Sweden)
- CNR
- DTU - Technical University of Denmark
- ENEA
- EPFL – École Polytechnique Fédérale de Lausanne
- Ferrari Technology
- Graf Spa
- Star Engine
- University of Ferrara

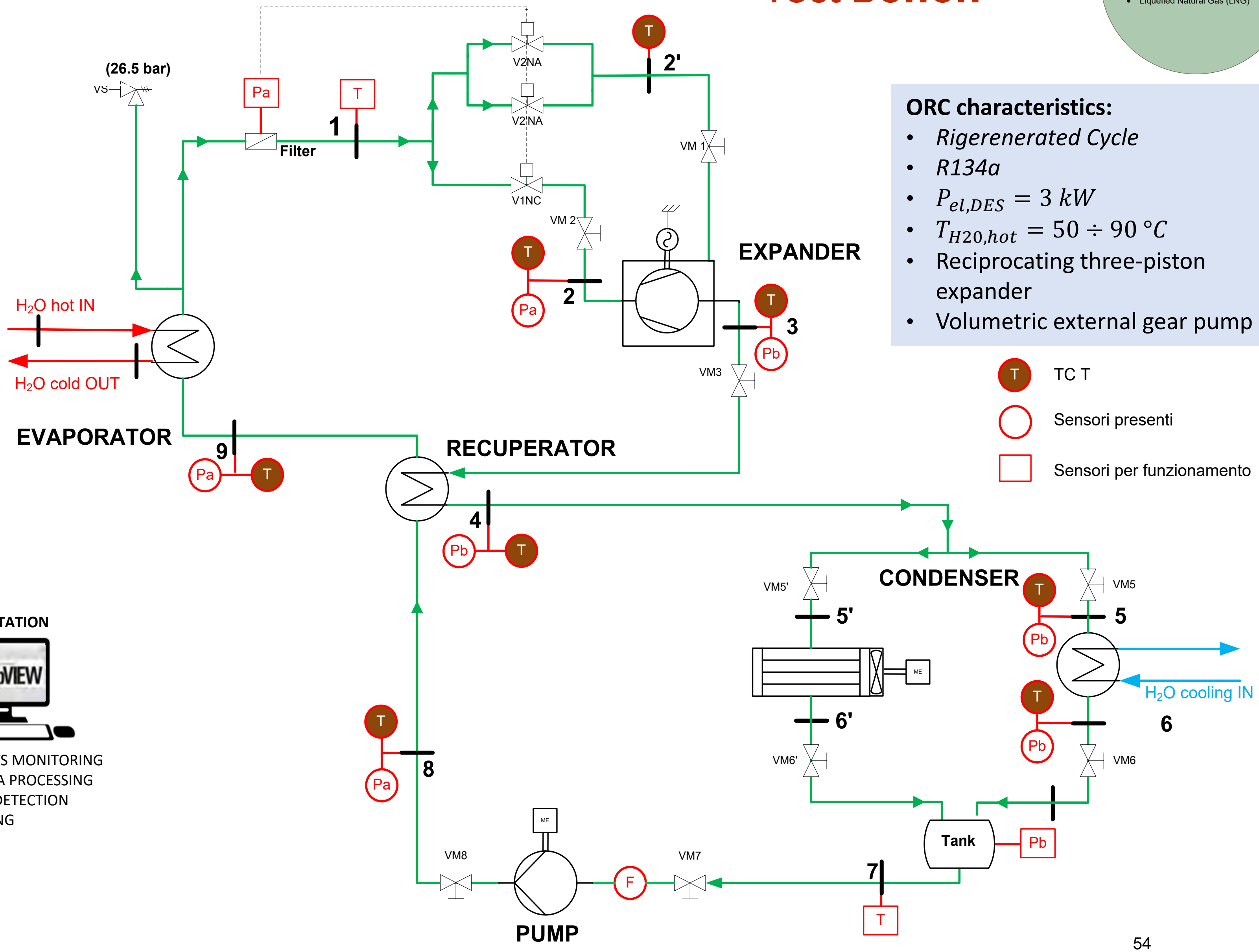
MINI GRID



GENERATION SYSTEMS: **ORC LABORATORY**

GENERATION SYSTEMS AND STORAGE TECHNOLOGIES:
- ORC Laboratory
- Ravenna Laboratory
- Power-to Gas (P2G)
- Liquefied Natural Gas (LNG)

Test Bench



ORC characteristics:
- *Rigenerated Cycle*
- *R134a*
- $P_{el,DES} = 3\ kW$
- $T_{H20,hot} = 50 \div 90\ °C$
- Reciprocating three-piston expander
- Volumetric external gear pump

T	TC T
○	Sensori presenti
□	Sensori per funzionamento

SENSORS

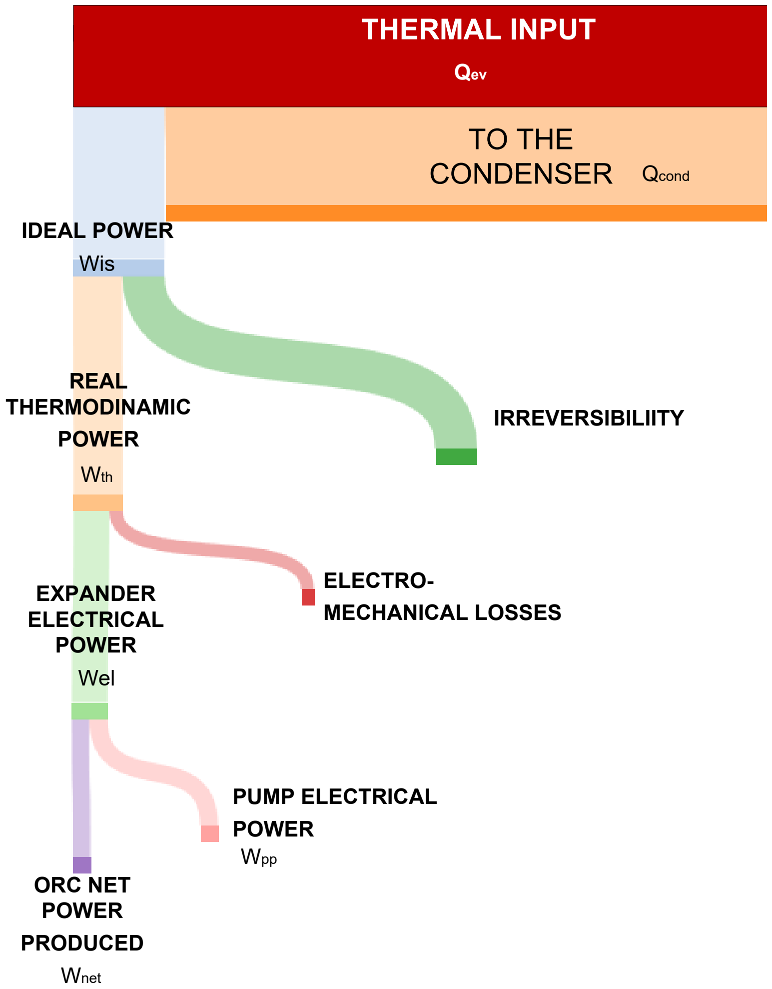
INPUT HARDWARE
NI CRIO

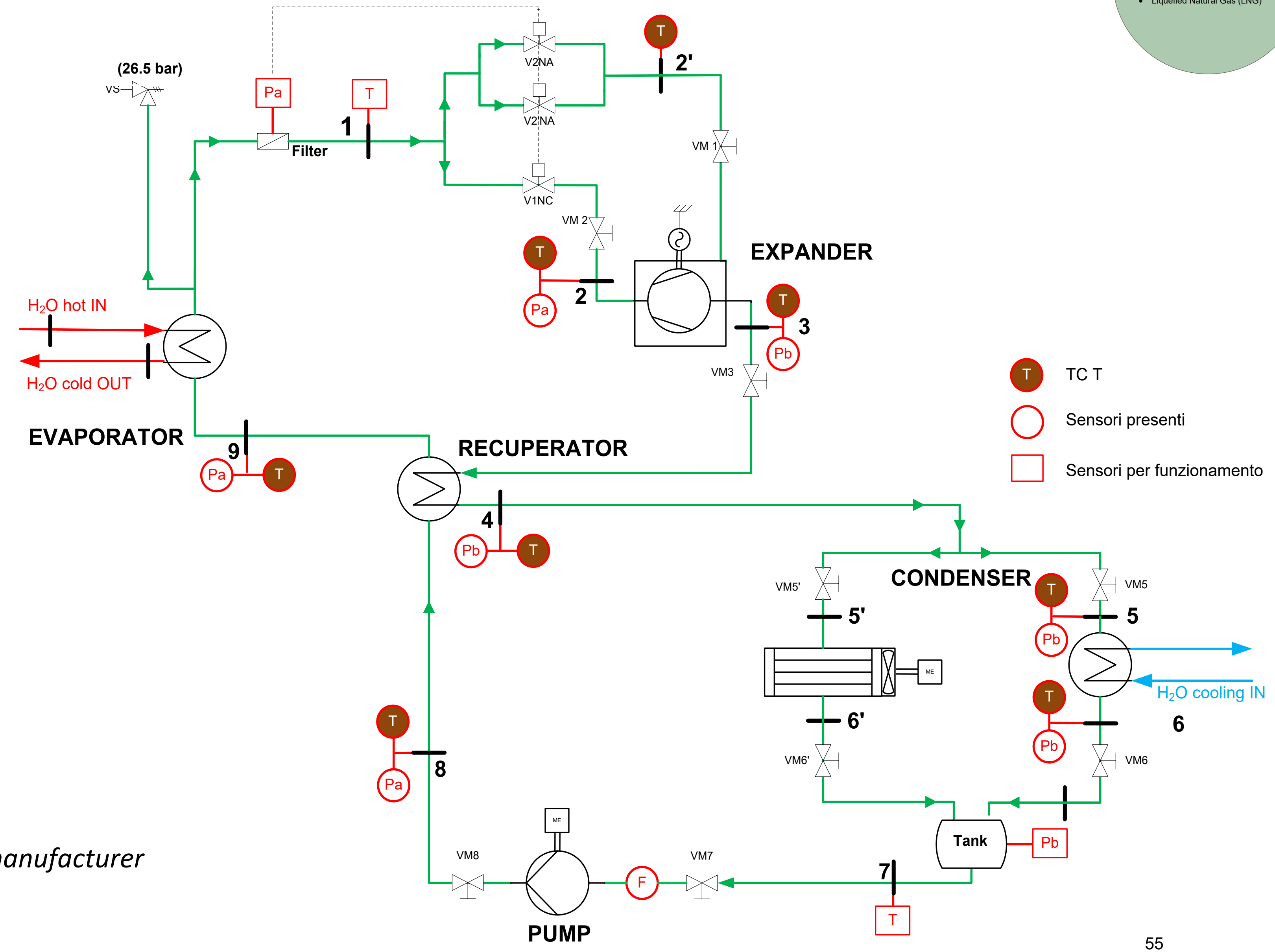
- SIGNAL CONDITIONING
- SIGNAL TRASDUCTION

PC WORKSTATION

- MEASUREMENTS MONITORING
- REAL TIME DATA PROCESSING
- STEADY STATE DETECTION
- DATA RECORDING

GENERATION SYSTEMS: **ORC LABORATORY**



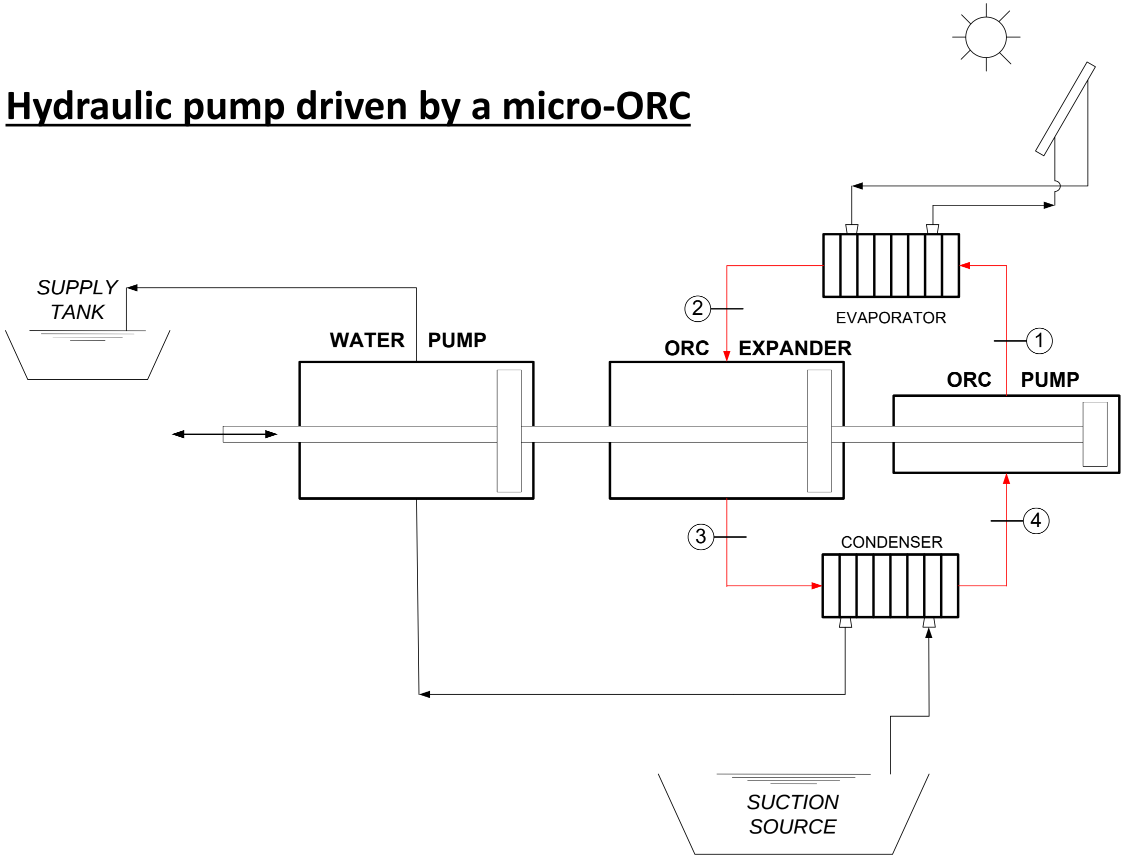


<u>Collaboration</u>: University of Ferrara, Star Engine – ORC manufacturer

GENERATION SYSTEMS: **ORC LABORATORY**

Test Bench

Hydraulic pump driven by a micro-ORC



System characteristics:
- $R134a$
- $Pressure\ Head = 0.6 \div 1.8\ bar$
- $T_{H20,hot} = 50 \div 75\ °C$
- $T_{H20,cold} = 24 \div 26\ °C$
- Pump and expander: double acting-piston machines
- No electronic control system required

GENERATION SYSTEMS AND STORAGE: **RAVENNA LABORATORY**

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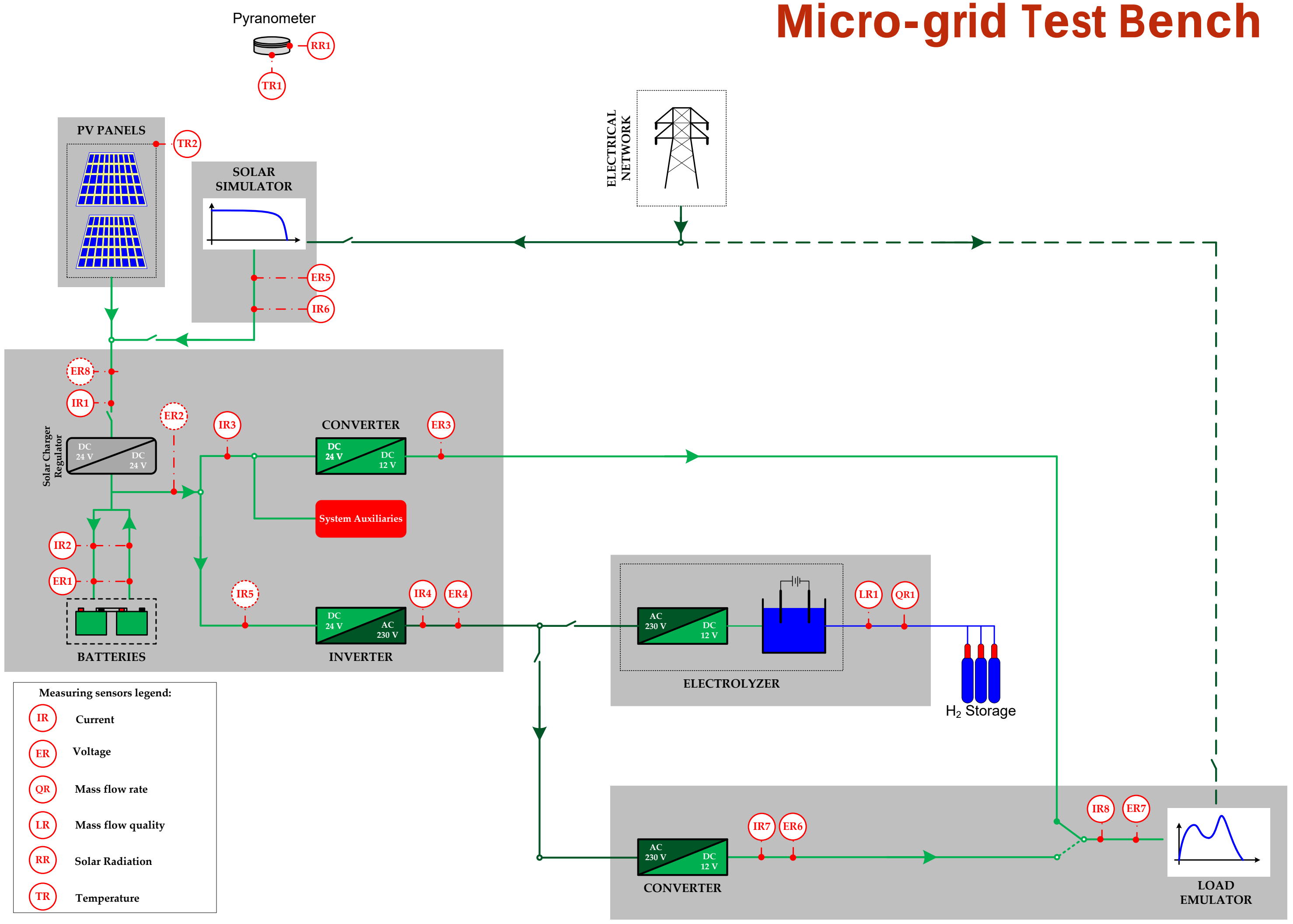
Micro-grid Test Bench



SYSTEM	
MAX. INPUT CURRENT, PHOTOVOLTAICS	30 A
SYSTEM VOLTAGE, PHOTOVOLTAICS	24 V DC
MAX OUTPUT CURRENT 12 V DC	2 A
MAX. CONTINUOUS OUTPUT 230 V AC	700 W
MOMENTARY PEAK LOAD	1050 W (10 SEC)
OUTPUT VOLTAGE FREQUENCY	230 V, 50/60 HZ, TRUE SINUS

SOLAR MODULES (EACH)	
TYPE	POLYCRYSTALLINE
SYSTEM VOLTAGE	24 V DC
MPP OUTPUT	220 W
EFFICIENCY	>13% @AM1.5
SHORT CIRCUIT CURRENT	8.62 A
MPP VOLTAGE	27.54 V

BATTERIES (EACH)	
TYPE	LEAD-ACID BATTERY
SYSTEM VOLTAGE	12 V DC
CAPACITY	55 AH

HYDROGEN GENERATOR	
TYPE	PROTON EXCHANGE MEMBRANE
PRODUCTION CAPACITY	30 SL/H @10.7 BAR
HYDROGEN PURITY	6.0 (99.999%)
INPUT VOLTAGE	120 VAC /50- 60 HZ
MAX. CONSUMPTION	300 VA

ELECTRONIC DC LOAD EMULATOR	
INPUT VOLTAGE RANGE	0-360 V
INPUT POWER RANGE	0-300 W
INPUT CURRENT RANGE	0-30 A

GENERATION SYSTEMS AND STORAGE: **RAVENNA LABORATORY**

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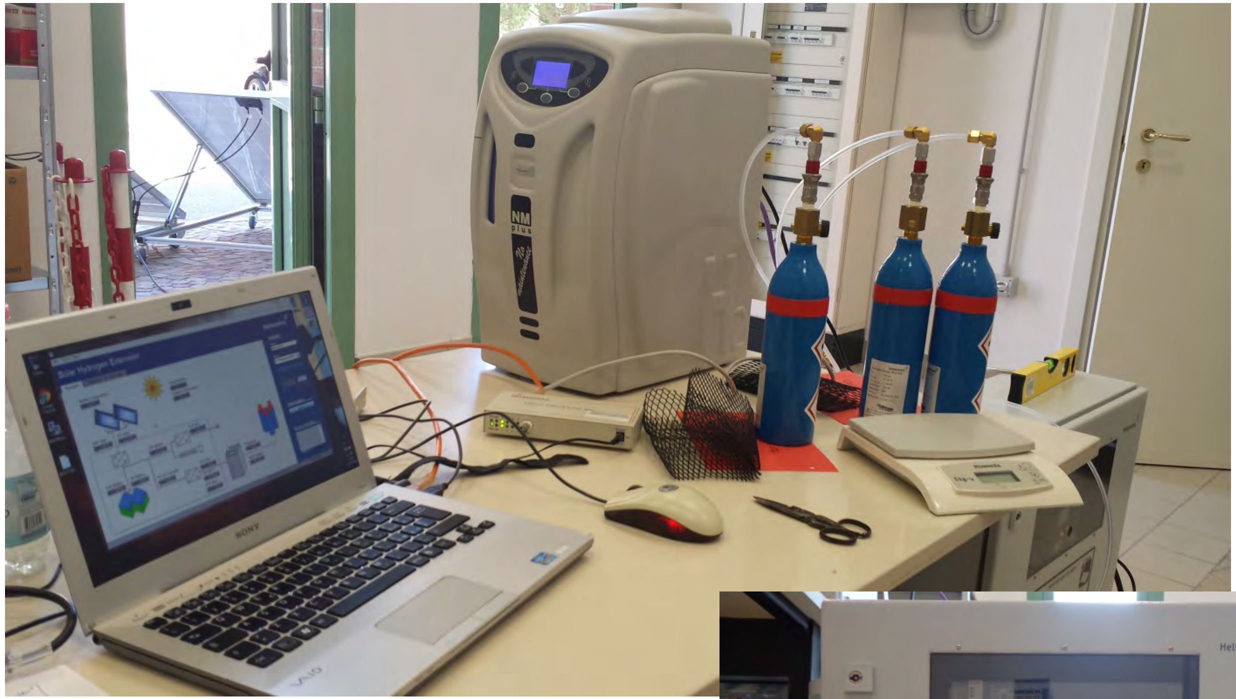

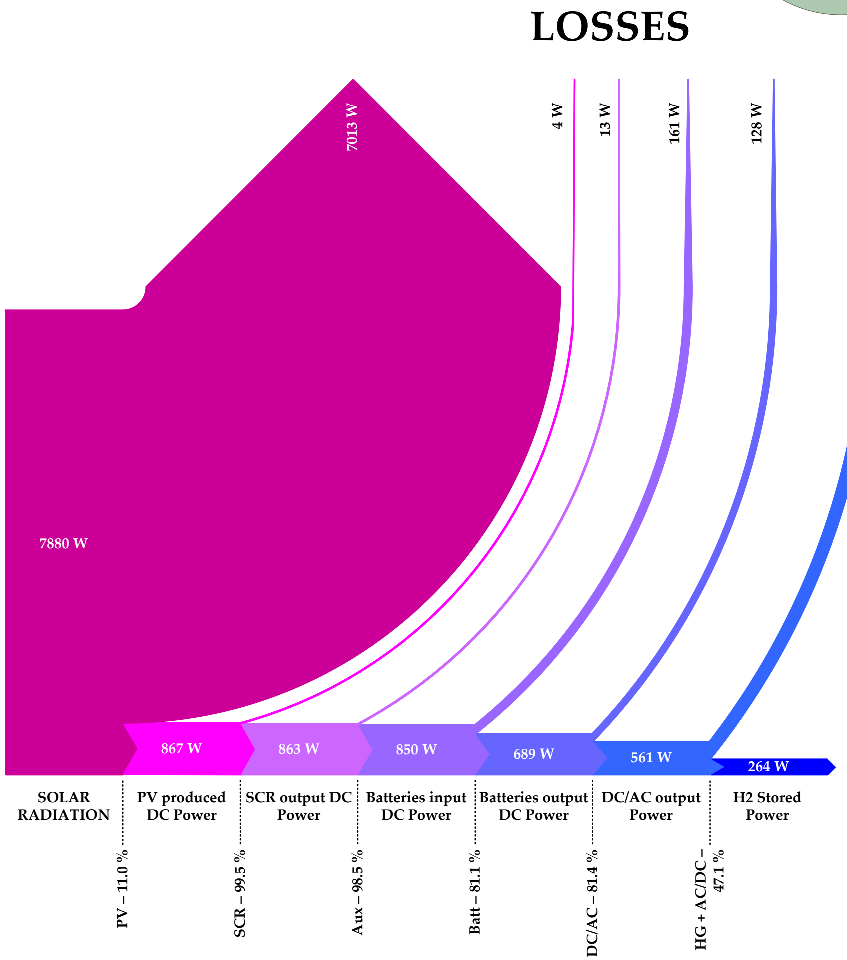

STORAGE TECHNOLOGIES: **POWER TO GAS**

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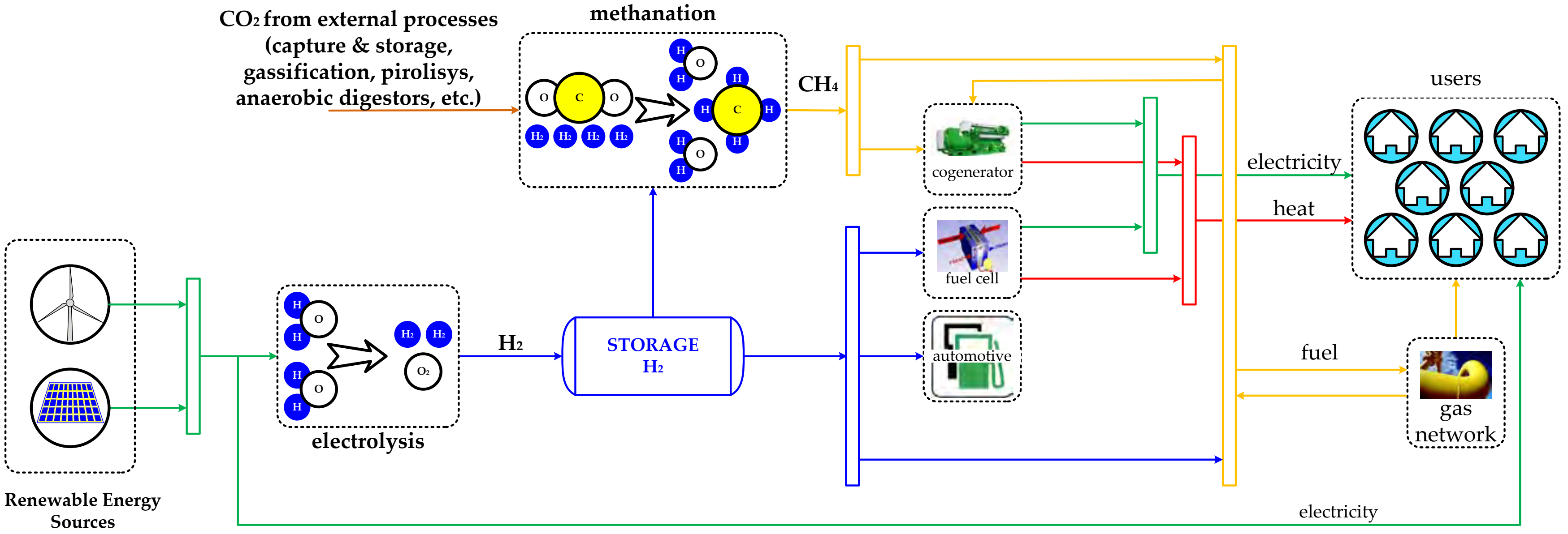
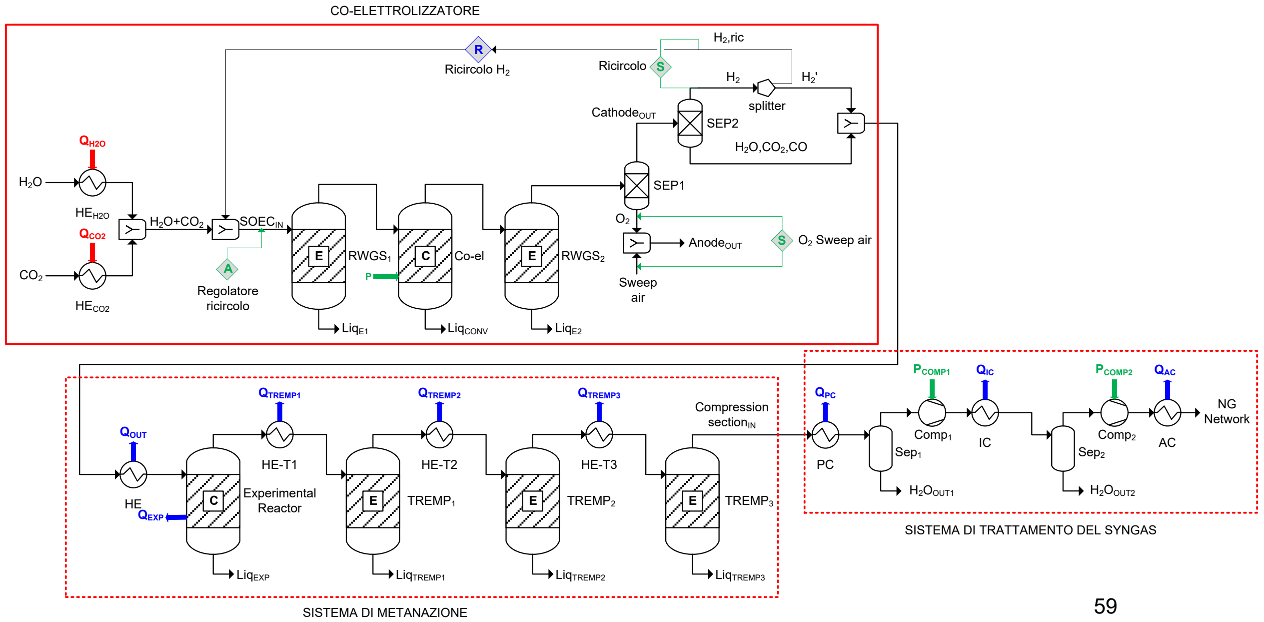


Production of Synthetic Natural Gas from renewables and CO_2 capture

Carried out analysis:

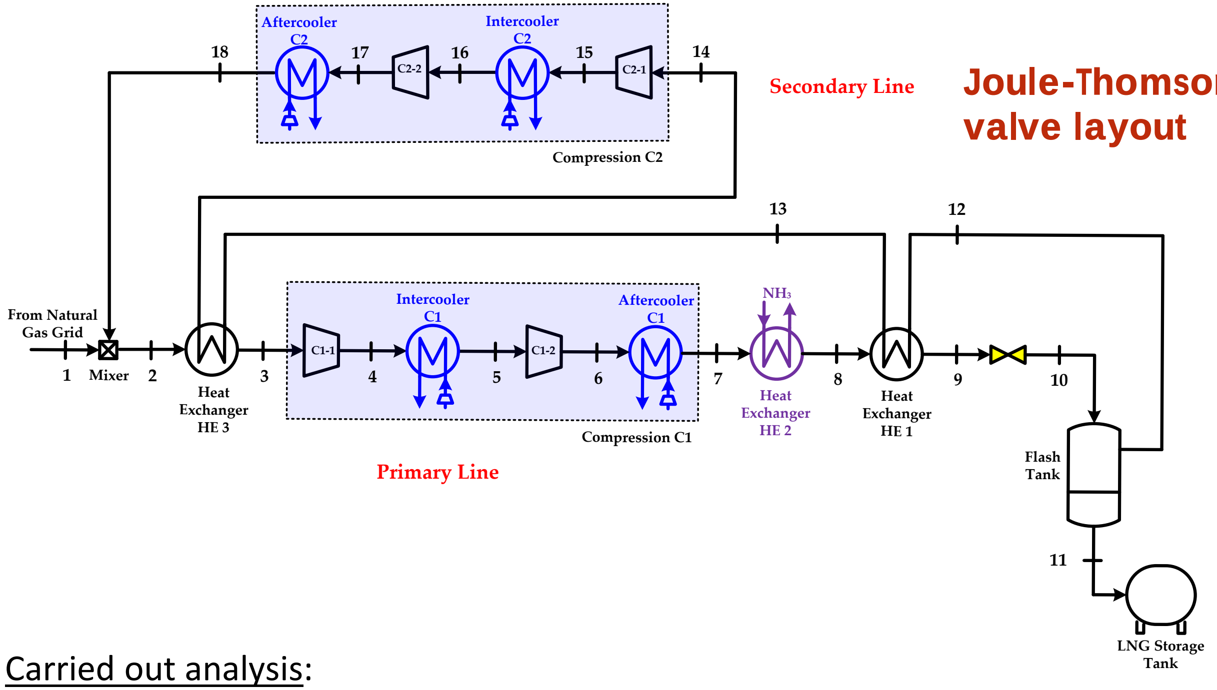
- **Model of the system** with ASPEN HYSIS
- **Electrolysis** and **methanation optimization**
- **Heat recovery** from different sections of the process
- **Performance** optimization

Collaboration: CNR – National Council of Research

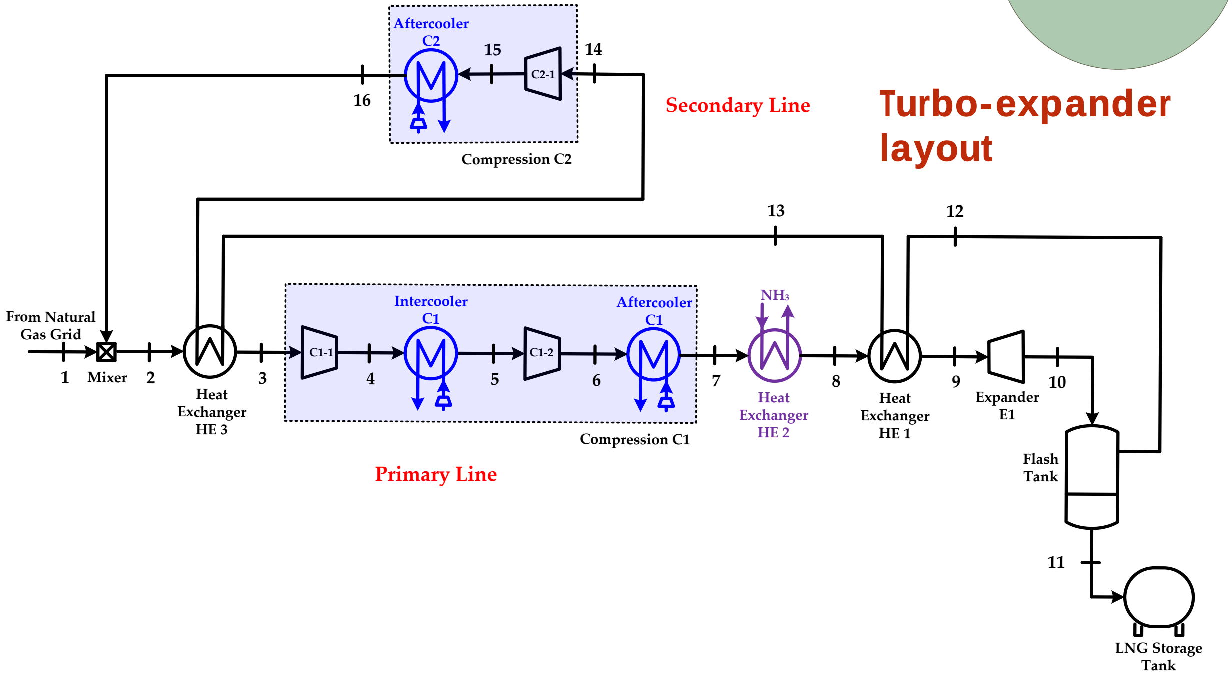


STORAGE TECHNOLOGIES: **LNG**

Joule-Thomson valve layout



Turbo-expander layout

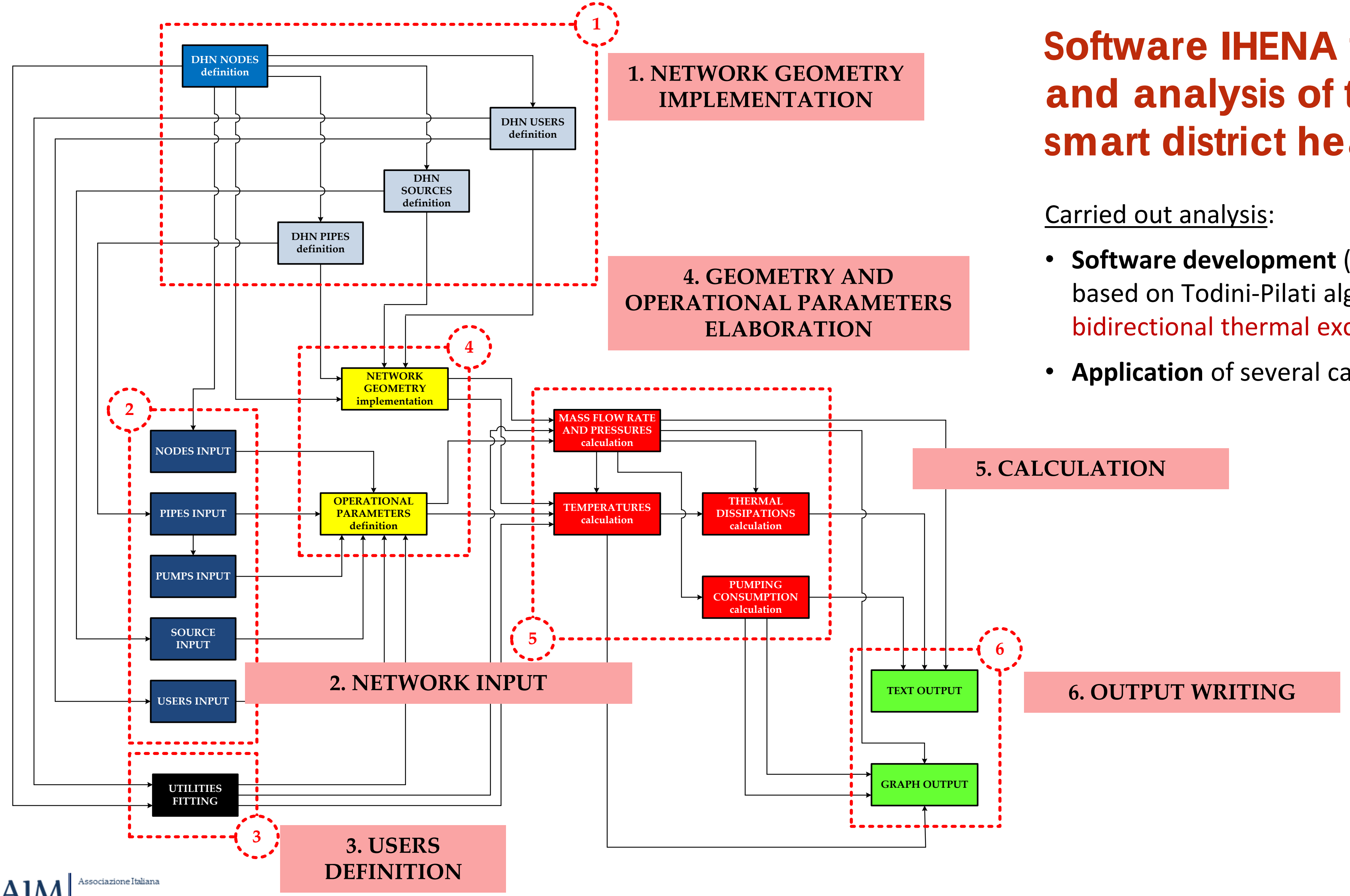


Carried out analysis:

- **Layout** definition and optimization (minimum compressors consumption, heat exchange optimization)
- **Parametric analysis** for the process optimization: maximum pressure, storage pressure, chiller outlet temperature
- **Performance evaluation**
- Waste heat recovery analysis and possible integration with bottoming cycles

*Collaboration: Graf S.p.a. (**prototype** realization), Clean Port project (POR-FESR 2014-2020)*

THERMAL DISTRIBUTION NETWORKS: **SOFTWARE IHENA**



Software IHENA for the design and analysis of traditional or smart district heating networks

Carried out analysis:

- **Software development** (thermo-hydraulic resolution of the network based on Todini-Pilati algorithm, introduction of the possibility of bidirectional thermal exchange at final users)
- **Application** of several case studies

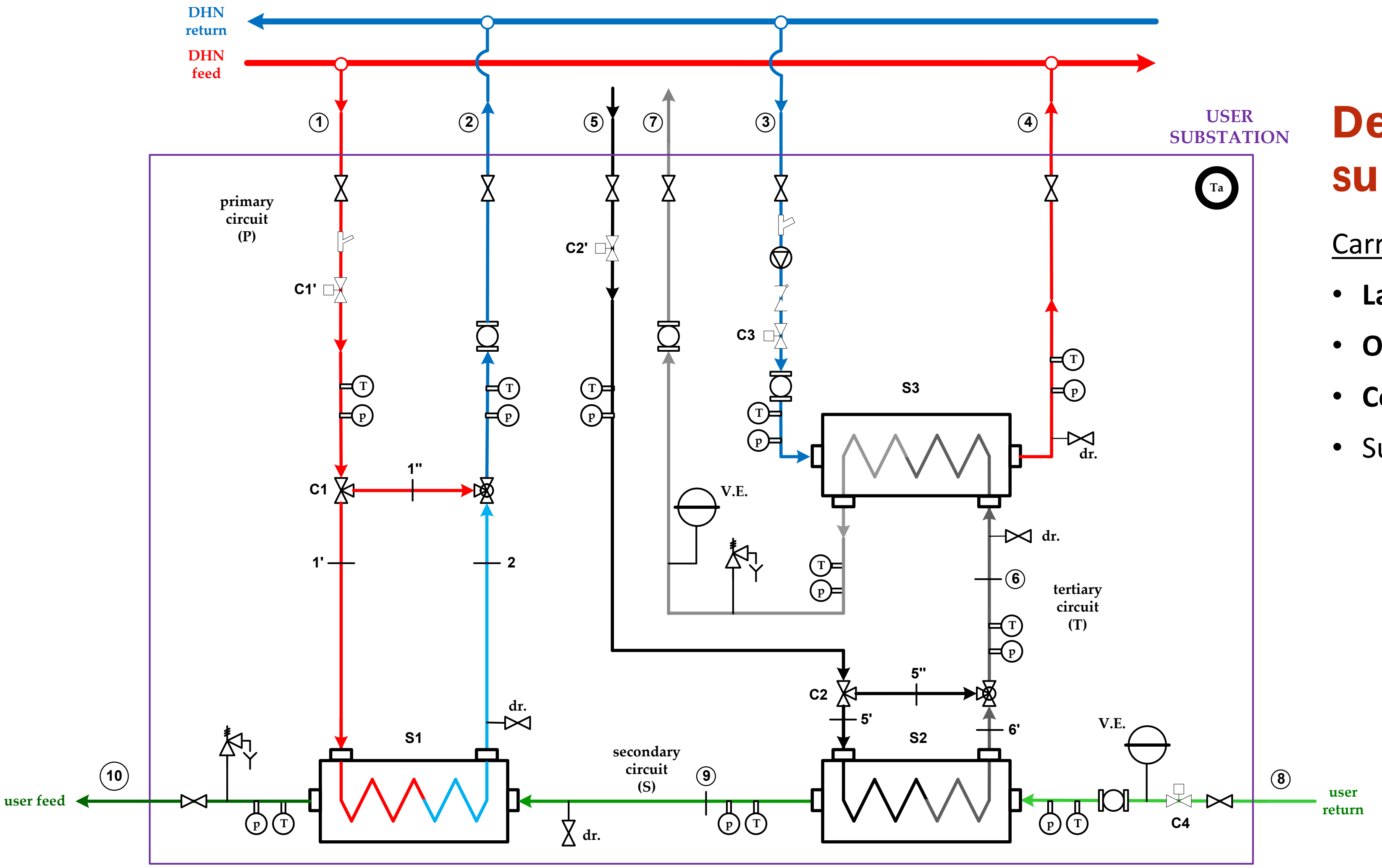
Main output:

- inlet and outlet **temperature** and **pressure**, mass flow rate, velocity, pressure drop for each pipe
- total **heat supplied** from the production plants
- total **electrical power consumption** for the pumping stations
- **pressure drops** at each of primary circuits of the utilities

THERMAL DISTRIBUTION NETWORKS: **SMART DISTRICT HEATING**

THERMAL DISTRIBUTION NETWORKS:

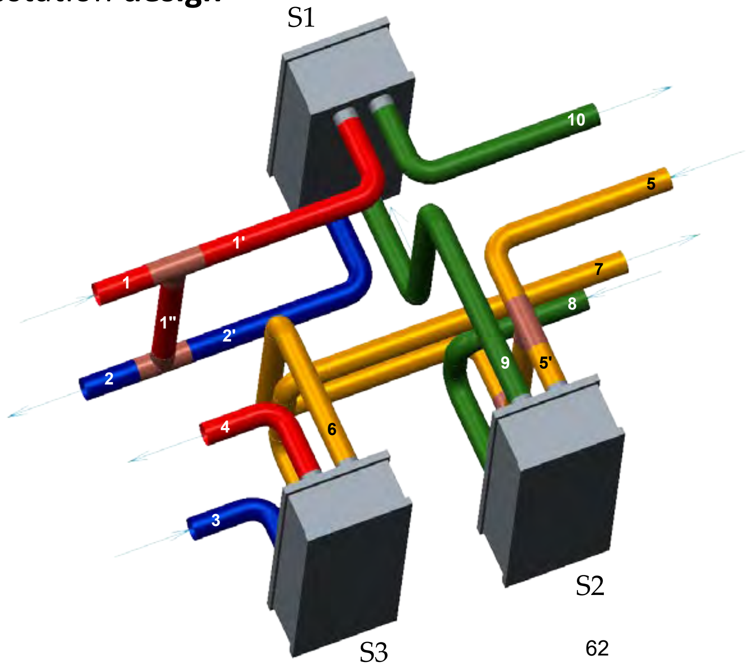
- Software IHENA
- Smart District Heating



Design *ex novo* of a smart user substation

Carried out analysis:

- **Layout (strategy)** definition
- **Operational logic** definition
- **Control** definition
- Substation **design**



Collaboration: ENEA (Italian National Agency for New Technologies, Energy and Sustainable Economic Development) and Eurac Research

STRATEGIES FOR OPTIMAL MANAGEMENT IN POLYGENERATION GRIDS: **SOFTWARE EGO**

Software EGO for energy systems' scheduling optimization

✓ **Scheduling optimization** with the aim to **minimize the total cost of energy production**

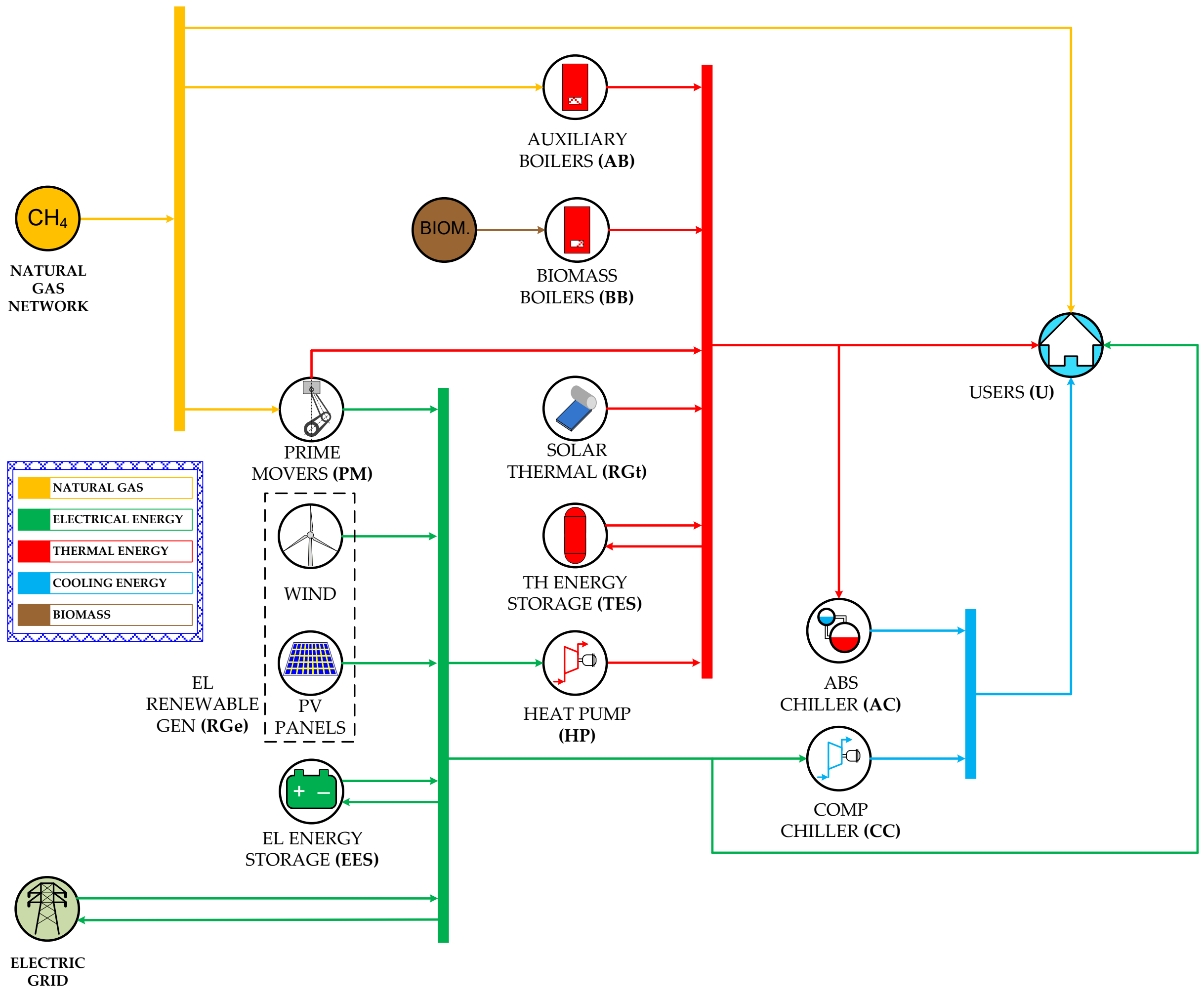
✓ Based on **genetic algorithms**

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

- C_λ: fuel cost
- C_M: maintenance costs
- C_E: electricity purchase costs
- C_F: fictitious costs

Thermal Priority $$C_F = \sum_{i=1}^{n_{PM}} \frac{Q_{disp,i}}{\eta_{AB,av}} \cdot \lambda_{fuel} \cdot p_T - P_{EL,S} \cdot \xi_{EL,S}$$

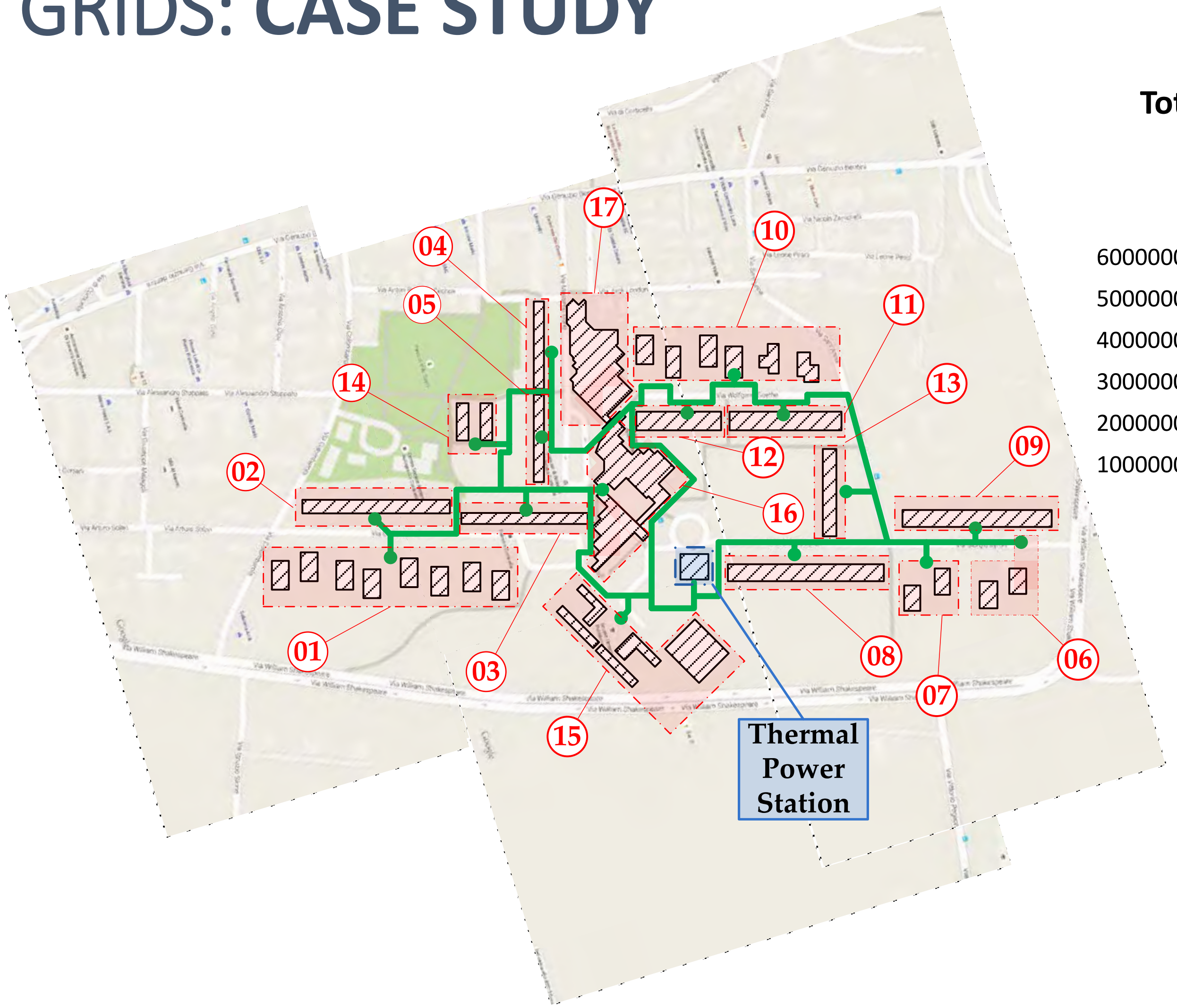
Electrical Priority $$C_F = P_{EL,S} \cdot \xi_{EL,S} \cdot p_E$$

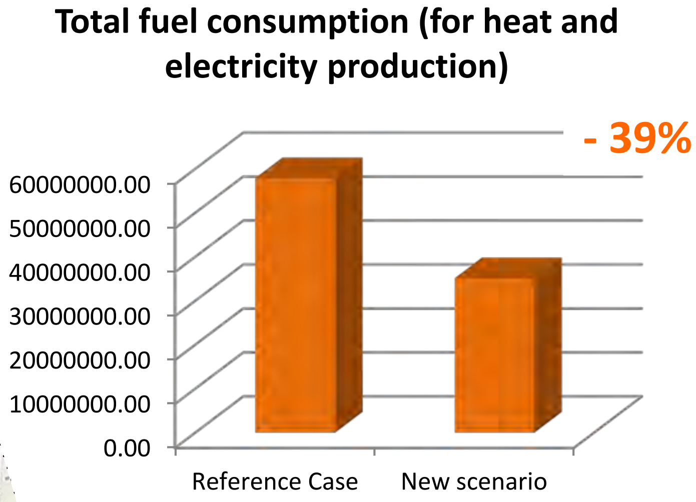


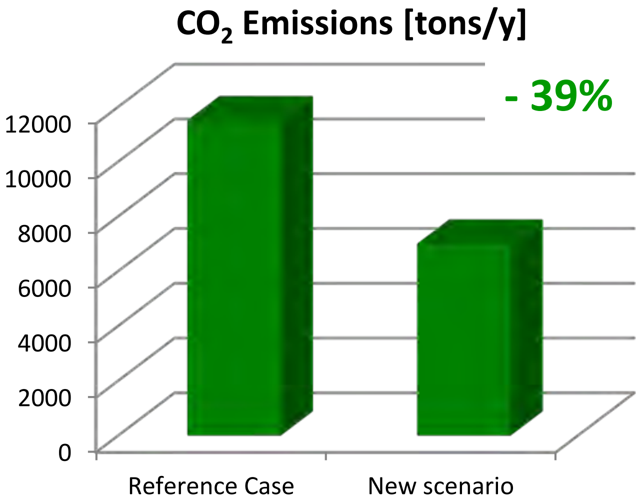
STRATEGIES FOR OPTIMAL MANAGEMENT IN POLYGENERATION GRIDS: **CASE STUDY**

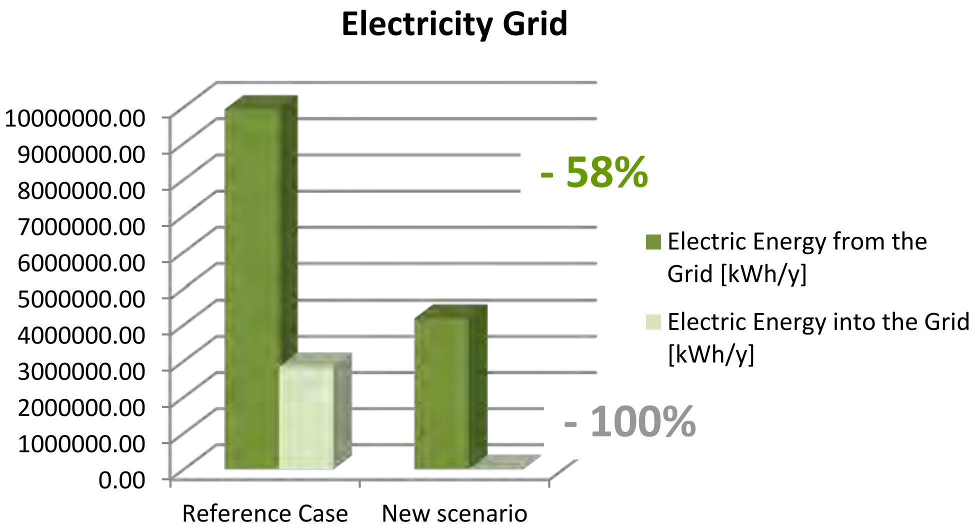
STRATEGIES FOR OPTIMAL MANAGEMENT IN POLYGENERATION GRIDS:

- Software EGO – genetic algorithms









<u>Collaboration</u>: ENEA, Efficity project (POR-FESR 2014-2020)

AIM SEA
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