POLITECNICO MILANO 1863

# GECOS research activities on multi-energy systems and microgrids

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Gecos Group of Energy COnversion Systems

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# THE DEPARTMENT OF ENERGY @ POLITECNICO, DIVISIONS & GECOS GROUP



The Department of Energy at Politecnico joins researchers originally belonging to 5 divisions.
It has ~130 permanent researchers and professors

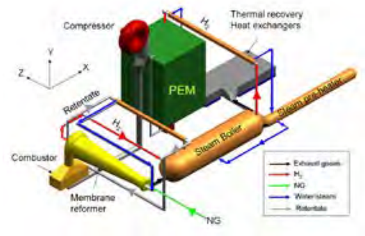
1. Chemical Technologies and Processes and NanoTechnologies Division
2. Electrical Division
3. Nuclear Engineering Division
4. Thermal Engineering & Environmental Technologies Division
5. Fluid Dynamic Machines, Propulsion & Energy Systems Division
   - Fluid-dynamics of turbomachines
   - Internal combustion engines
   - Propulsion and combustion
   - *Group of Energy COnversion Systems (GECOS):*

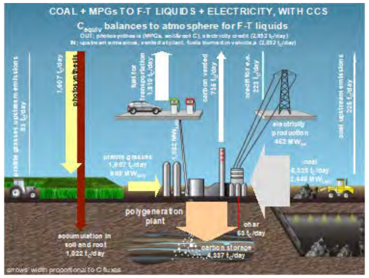
     *3 Full professors*
     *9 Tenured associate/assistant professors*
     *6 RTDA (assistant professors)*
     *4 Post docs*
     *5 Temporary researchers*
     *10 PhD students*

# MAIN RESEARCH AREAS



1. **CARBON CAPTURE TECHNOLOGIES**
2. **RENEWABLE ENERGY SOURCES AND WASTE-TO-ENERGY**
3. **HYDROGEN AND FUEL CELLS**
4. **ORC AND ADVANCED POWER CYCLES**
5. **MICRO-GRIDS AND MULTI-ENERGY SYSTEMS**
6. **MODELLING AND OPTIMISATION**



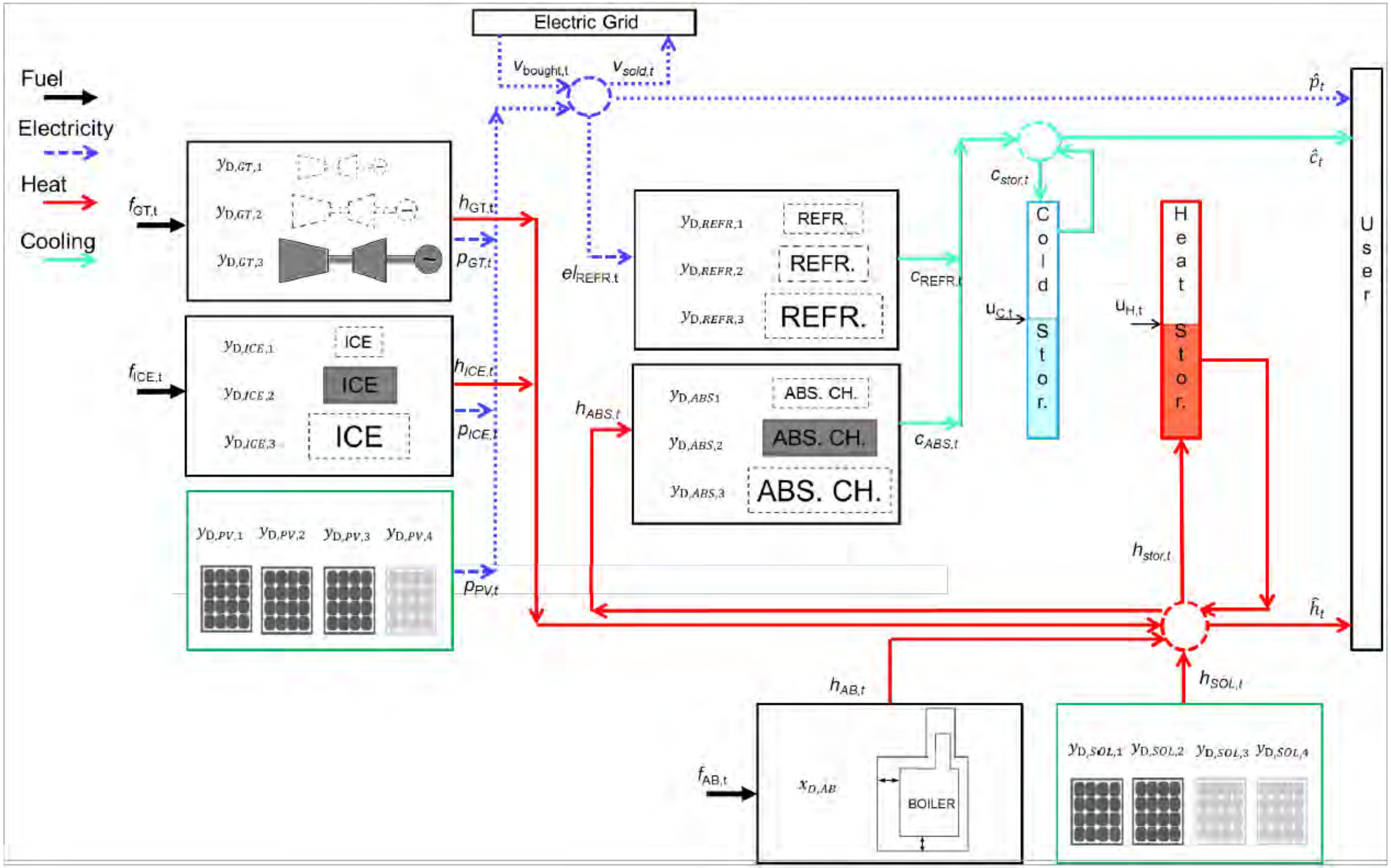


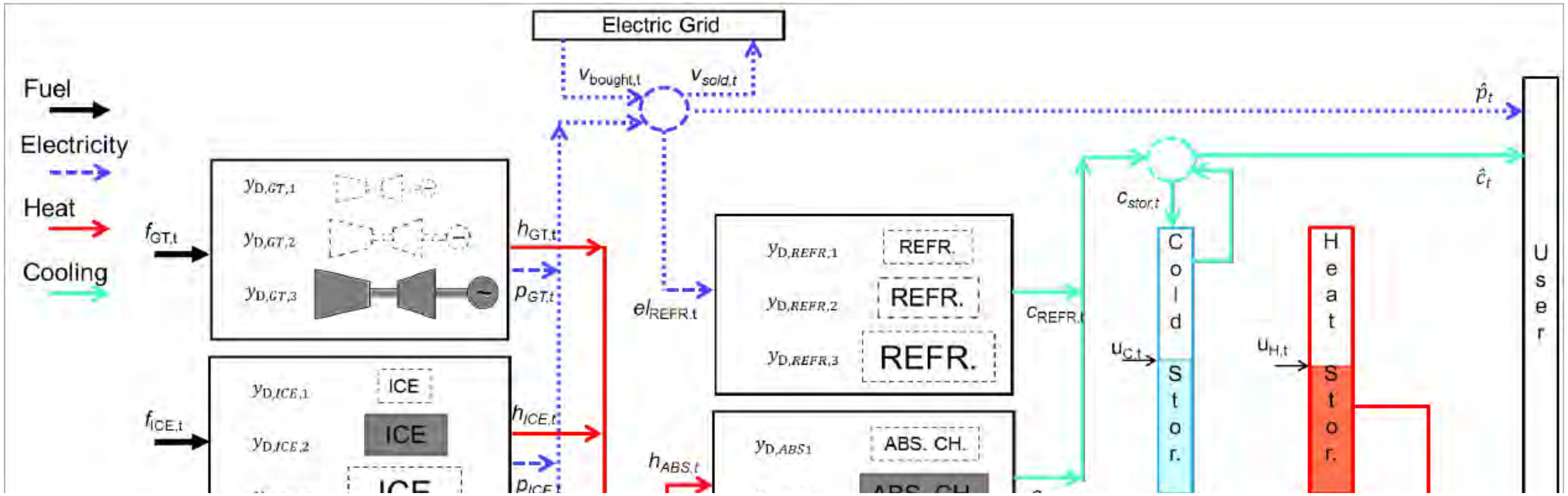
**> 10 ongoing EU + regional projects**

**Tens of ongoing research contracts with industries**

***http://www.gecos.polimi.it/***

# OPTIMIZATION OF MULTI ENERGY SYSTEMS AND MICROGRIDS






**Types of optimization problems associated to MES (for microgrids and DHC networks):**

1. **Design/retrofit of the system («investment planning»)**
2. **Long-term operation planning accounting for yearly constraints (incentives/seasonal storage)**
3. **Short-term scheduling (day-ahead unit commitment)**
4. **Optimal control (dynamic models of units and networks)**

## Research projects on *Urban MES*

1. Develoment of a code for the optimal scheduling of MES and CHP systems (funded by SIRAM)
2. EFFICITY, optimization of efficient MES for urban districts considering demand and renewable uncertainty (LEAP-Polimi, CIDEA, CIRI-EA, CERR) co-funded by Regione Emilia Romagna (POR-FESR 2014-2020)

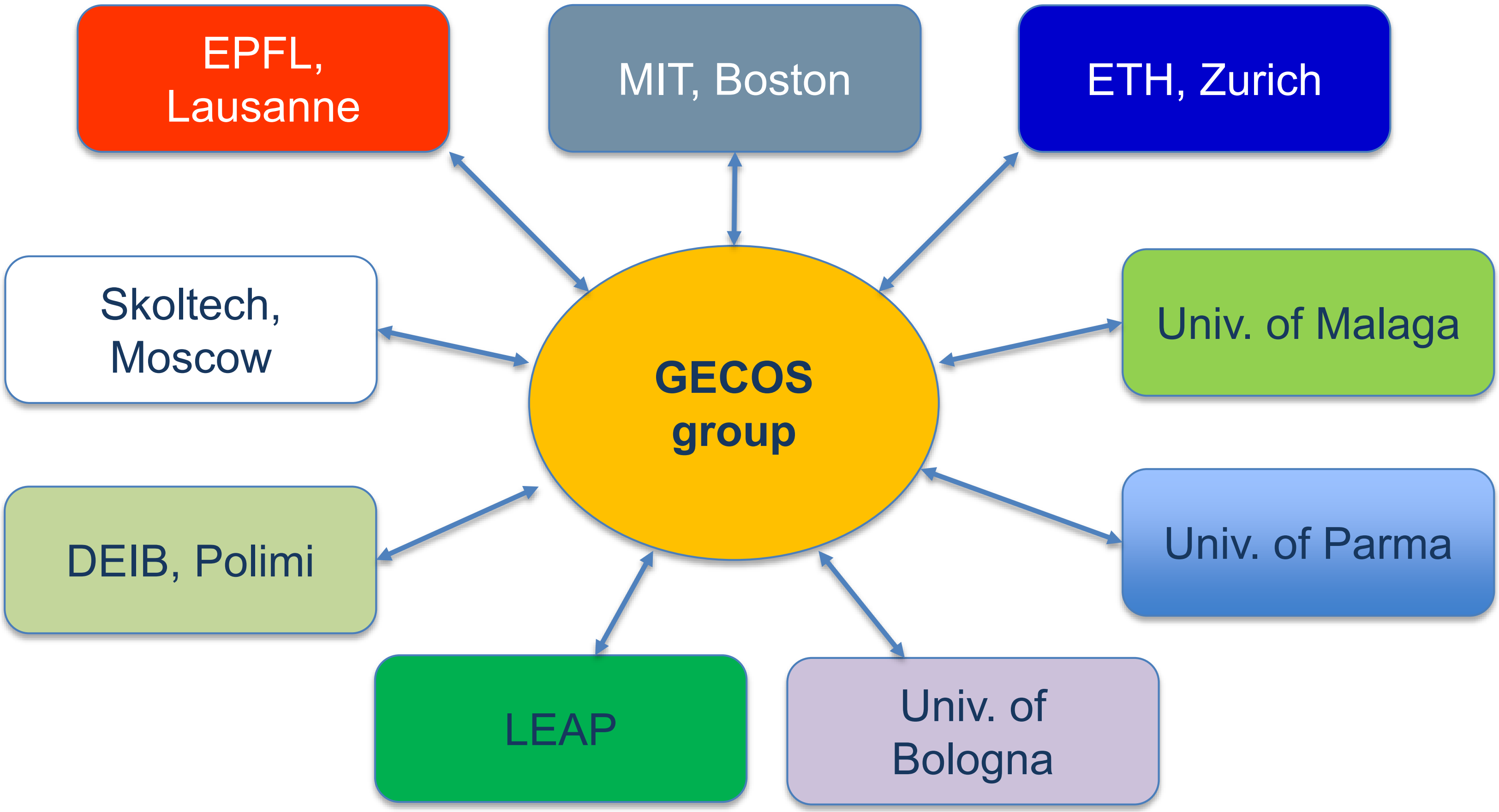
   *http://www.efficity-project.it/home-page-it*

## Research projects on Rural Microgrids

1. Optimal design and planning of microgrids for rural villages in Ghana and Mozambique (funded by Eni)
2. PROPHET, Design and test a control system for multi-good microgrids (funded by EPS) → microgrid lab test rig

**5 PhD students + 2 post docs working on MES and microgrids**

# OPTIMIZATION OF MES AND MICROGRIDS: ONGOING COLLABORATIONS

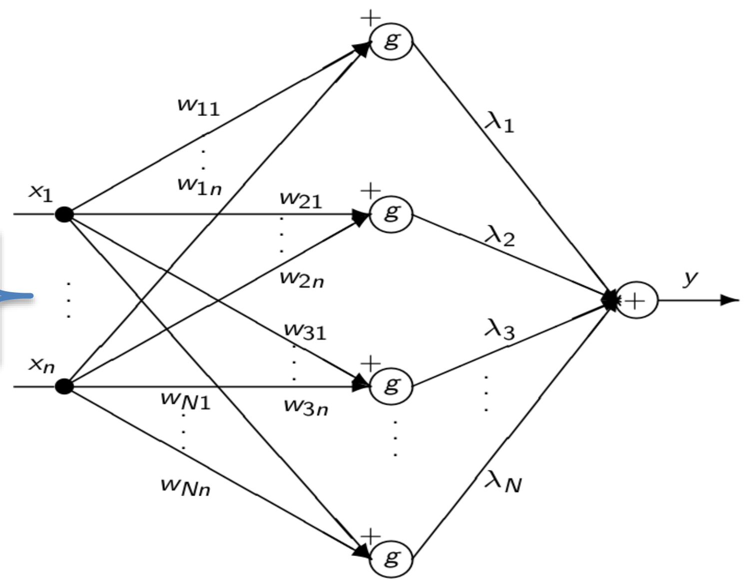


# DAY-AHEAD FORECAST WITH MACHINE LEARNING



TRAINING PERIOD FORECAST

- Wheather forecast
- Week day

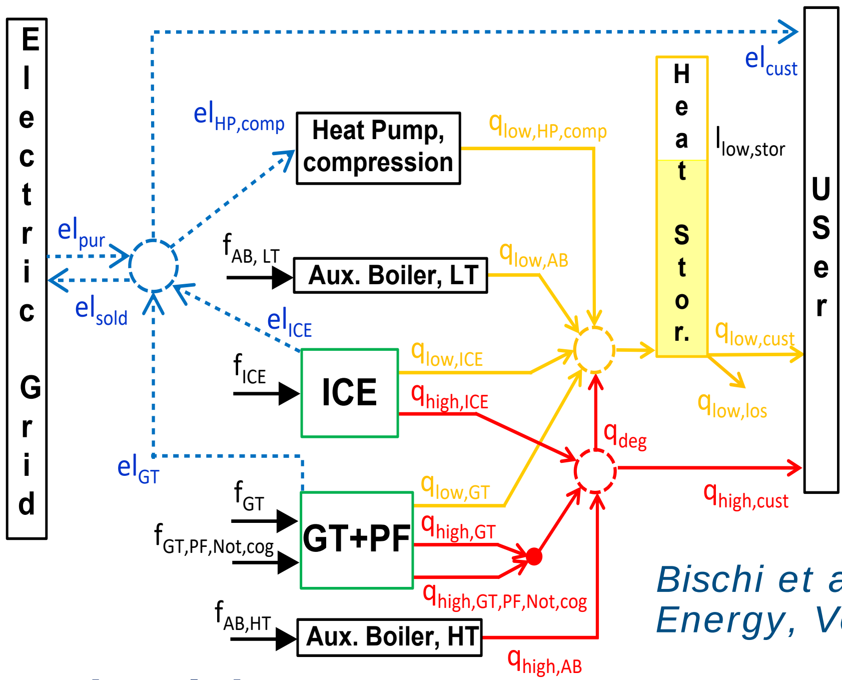



- -Heat demand
- -Cooling demand
- -Electricity demand

**Collaboration with group of Operations Research, prof. Amaldi and Dr. Manno**

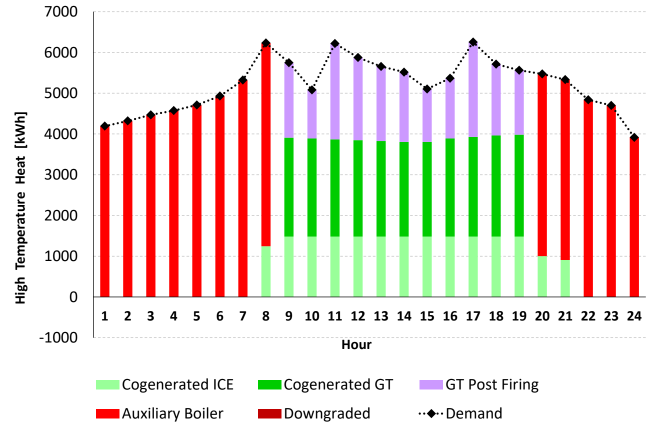
# DAY-AHEAD SCHEDULING: MILP MODEL



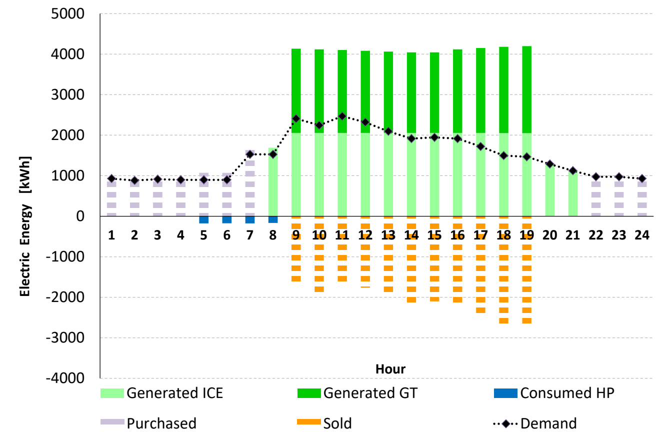



*Bischi et al. 2014. Energy, Vol. 74*

## High temperature heat




## Electricity




**Computational time:**

**1 day operation: < 1 sec**

**1 week operation: < 2 min**

**Up to 18% primary energy saving compared to usual operation strategies!**

# LONG-TERM PLANNING: ROLLING HORIZON ALGORITHM

**Motivations:**

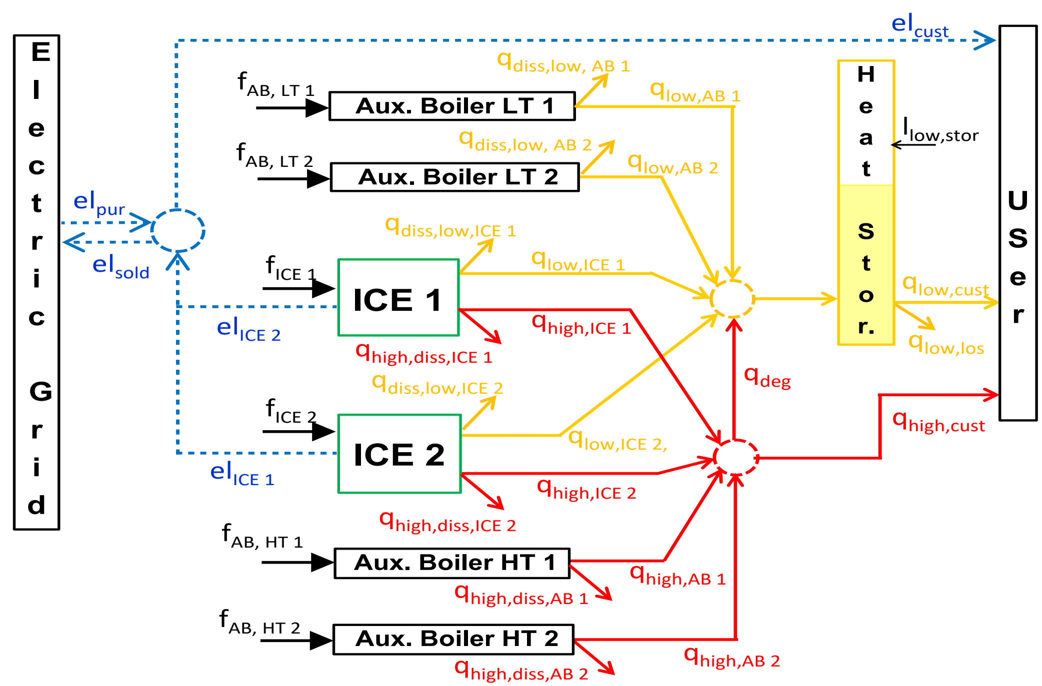
- **Cogeneration incentives (yearly basis)**
- **Seasonal storage systems**

**Operation must be optimized considering the whole year!**

**IDEA: *Rolling-horizon algorithm* (Bischi et al. 2018. Energy, in press)**

**Test case: CHP system of a large hospital**

**About 7% higher revenue compared to the weekly optimal operation.**



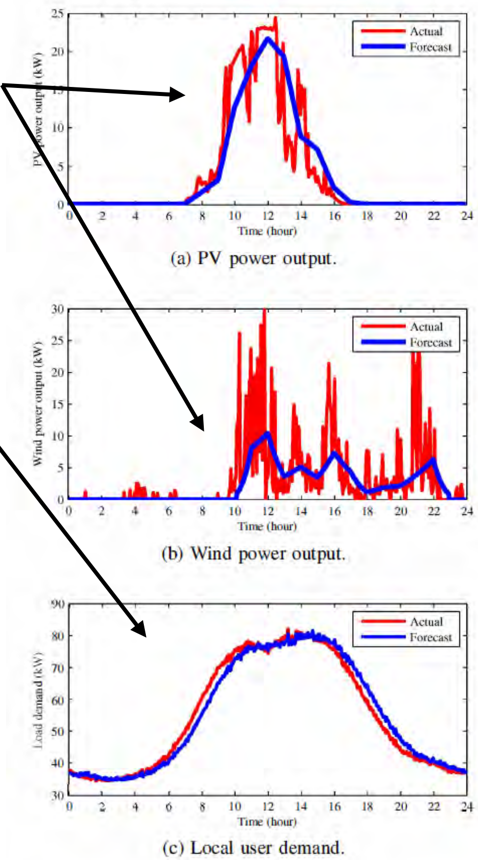

*Bischi et al. 2018. Energy (in press)*

# Optimal operation of MES and Microgrids under forecast uncertainty



## Given:

- → Forecast of power production from renewables and its uncertainty
- → Forecast of energy demand profiles and its uncertainty
- → Forecast of electricity prices and its uncertainty
- → Performance maps of the installed units
- → Operational limitations (start-up rate, ramp-up, etc) of units
- → Efficiency and Maximum capacity of storage systems



(a) PV power output.
(b) Wind power output.
(c) Local user demand.

## Determine:

**Nominal set-points:** on/off of units, nominal load of units, storage man.

**Correction rules:** how to adjust units loads during operation

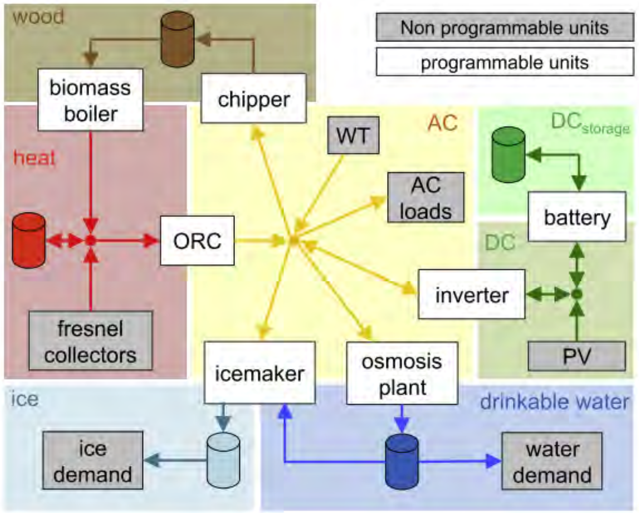
**Minimizing the daily operating cost in the most probable scenarios**

**Constraints:** meet energy demands, technical limitations of units, performance maps, etc

**IDEAS**: Use **Robust Optimization** and **Stochastic Programming** techniques (OR)

# Rural Microgrids Main Activities






- Optimization of highly integrated system architectures providing energy and services
- Performance evaluation of predictive dispatch strategies vs real-life operation
- Adoption of advanced optimization techniques for secure off-grid operation

# DESIGN OPTIMIZATION OF MES AND MICROGRIDS



Design-scheduling decompositiom

(*Elsido et al., 2017. Energy Vol. 121*)

Upper level (evolutionary alg.): optimizes design variables (selection/sizes)

Lower level: MILP scheduling problem

Avantages:

- Size effects accounted for on both performance and costs
- Possibility of considering many operating periods solved in sequence

Disadvantages:

- Slow convergence rate of evolutionary algorithms
- No optimality guarantee

Linearization without decomposition

(*Gabrielli et al. 2018, Applied Energy, in press*)

(*Zatti et al, 2017, Comp. Aided Chem. Eng., 40*)

Units' selection, sizes and operation optimized in a single large scale MILP

Advantages:

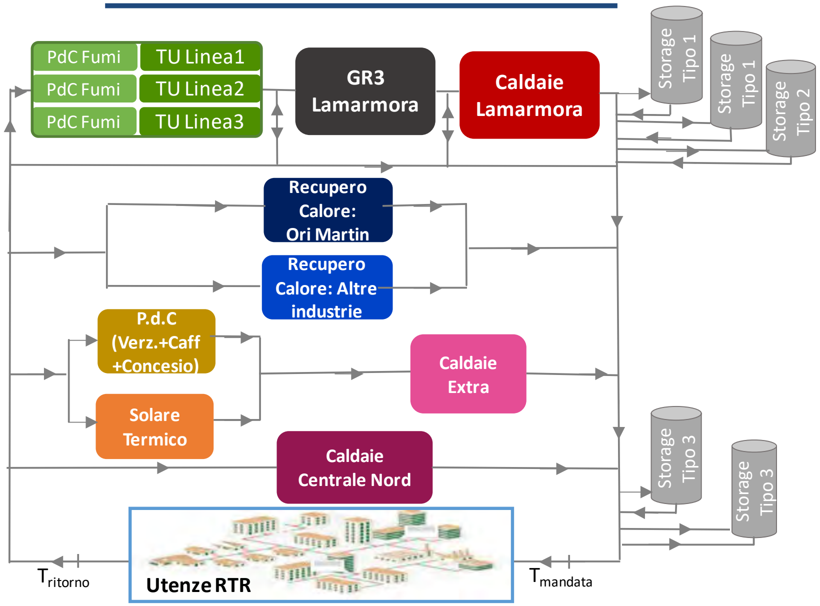
- Linear problem (computationally efficient)
- Global optimality guarantee
- Uncertainty can be rigorously handled via **stochastic programming** techniques

Disadvantages:

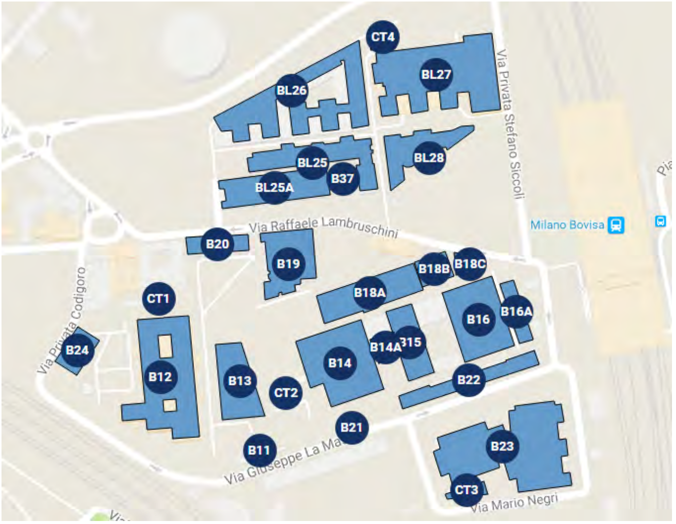
- Scale effects on investment costs must be linearized
- Size effects on efficiency must be approximated

# Optimal design of MES: Retrofit of DHC networks

## DH network of Brescia

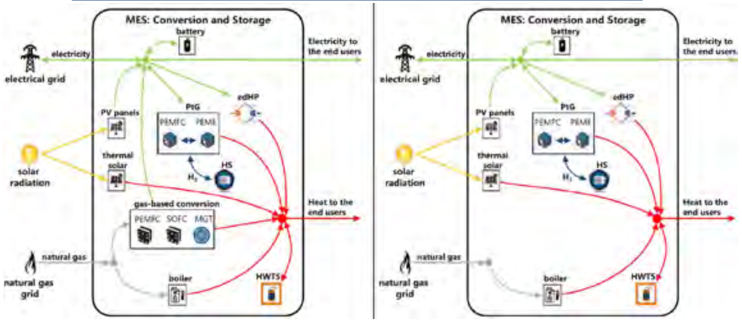



## Bovisa Campus




## University of Parma Campus (Efficity)

## Zurich district (with ETH)

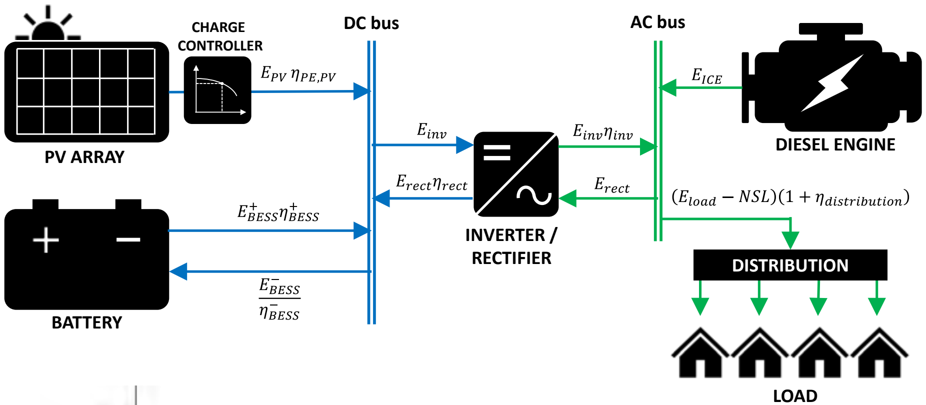



Gabrielli et al., 2018, Applied Energy, in press

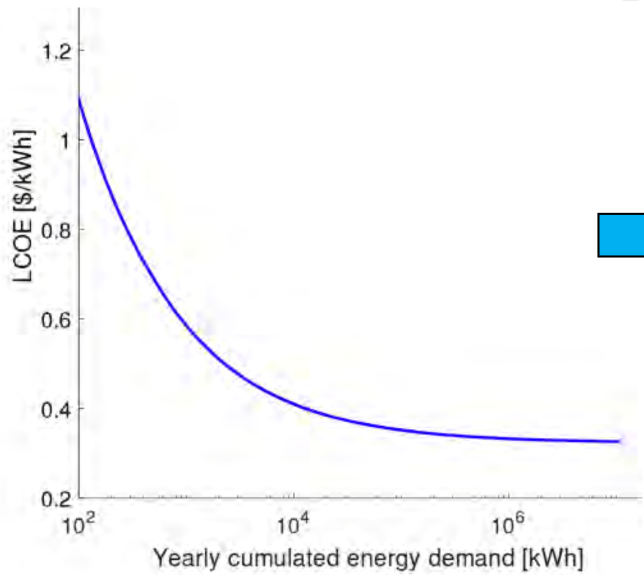
# Collaboration With MIT

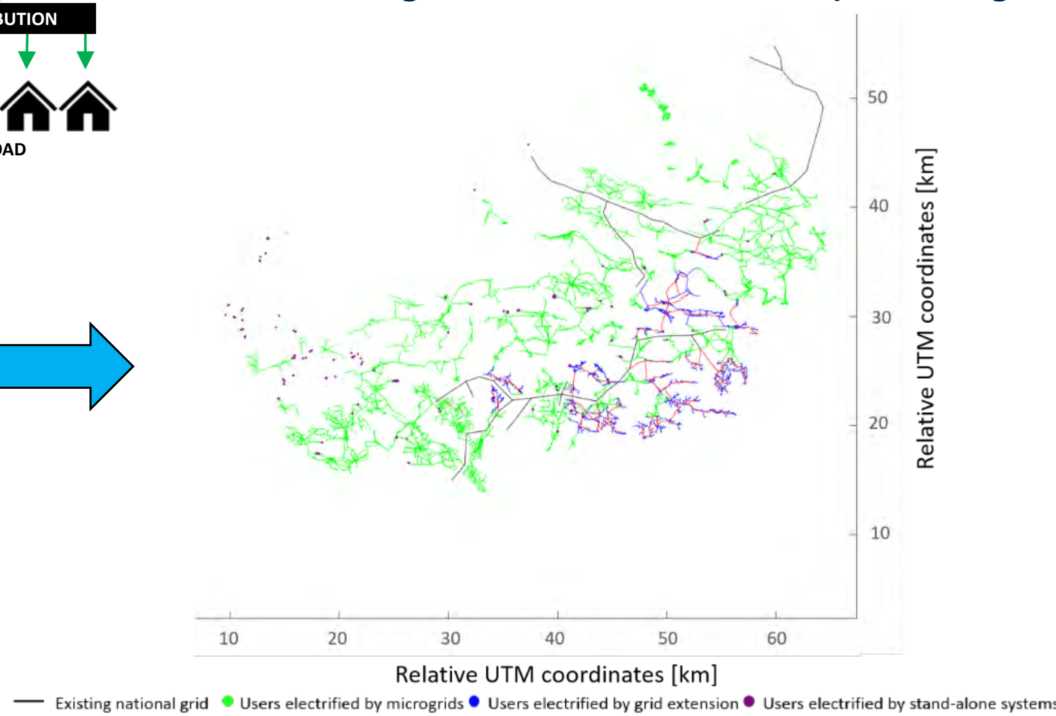


MIT Universal Access Lab and Polimi have been working together since a few years on microgrids for rural electrification.




The latest work dealt with the development of a discrete MILP-based investment optimization model, to be used for regional electrification planning



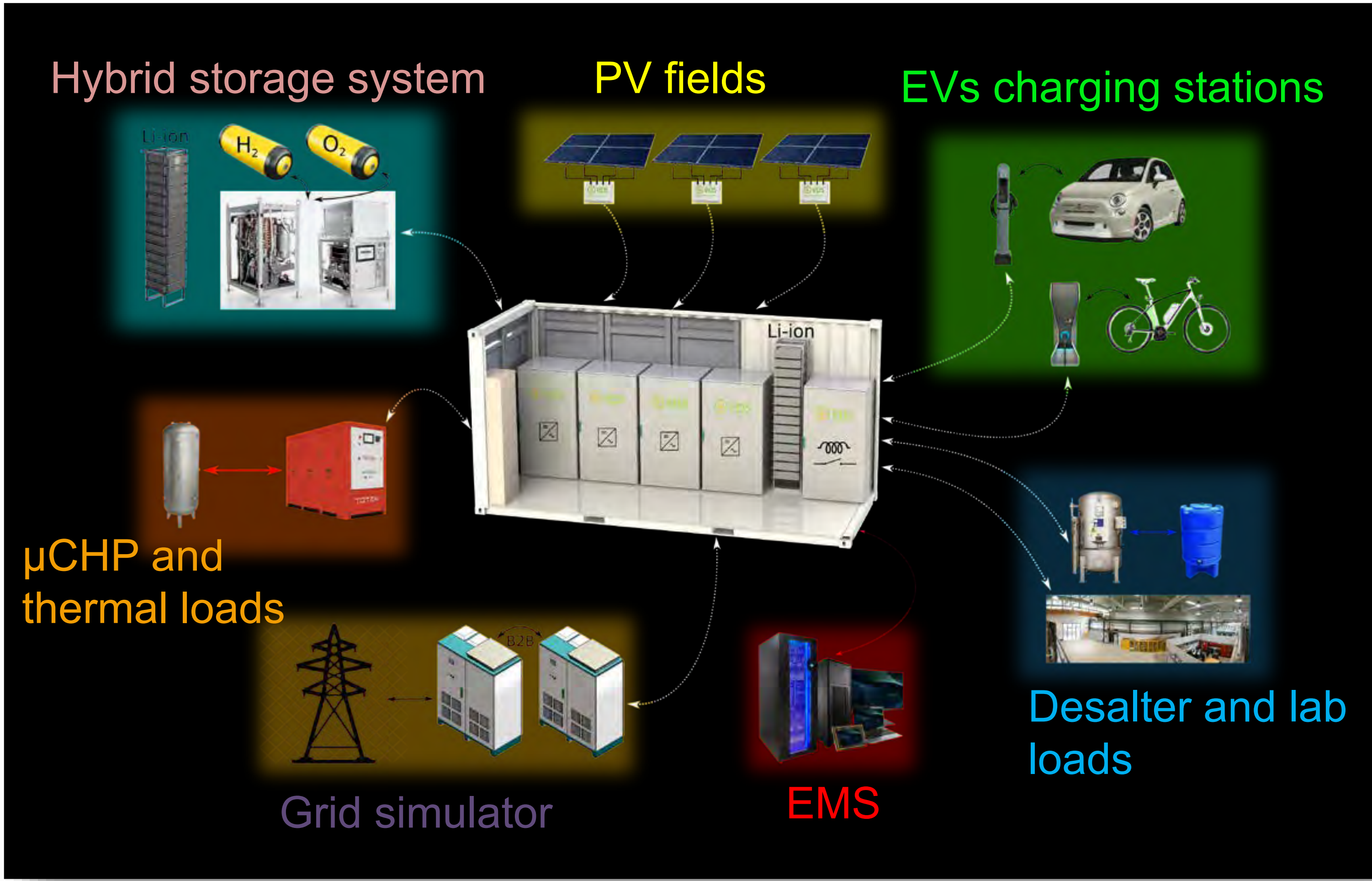



# MICRO-GRIDS LAB (MGL)

The **Micro-GridLab** (MGL) is an experimental facility currently under construction within the Department of Energy (inauguration date September 27th 2018).

MGL activities will focus on:

- Experimental testing of dispatch and control logics
- Validation of components modeling
- Interaction of microgrids and national grid /EV recharge systems



# Thank you for your attention!

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