

OEMOF WORKSHOP

EXPERIENCES IN OEMOF MULTI-PERIOD AND SNAPSHOT ANALYSES

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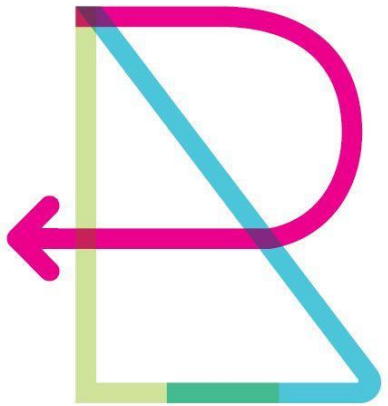
Stuttgart – 24-26 May 2023

Brief presentation of the groups ...

RELab

REnewable heating and cooling Lab

- 1 full professor
- 3 associate professors
- 5 assistant professors
- 15 PhD students / research assistants



R E L A B

RENEWABLE HEATING AND COOLING LAB

Research Areas:

- Renewable Heating and Cooling systems
- Energy efficient buildings
- District Heating and Cooling
- Energy Scenarios
- Life Cycle Assessment (LCA)

Gecos

Group of Energy Conversion Systems

- 6 full professors
- 7 associate professors
- 7 assistant professors
- 40 PhD students / research assistants



Research Areas:

- ORC and Advanced Power Cycles
- Renewable energy sources and waste-to-energy
- Carbon captures technologies
- Micro-grids and multi-energy systems
- Energy systems modelling and optimisation
- Fuel cell, hydrogen and electrochemical energy systems

Scope and summary of approach

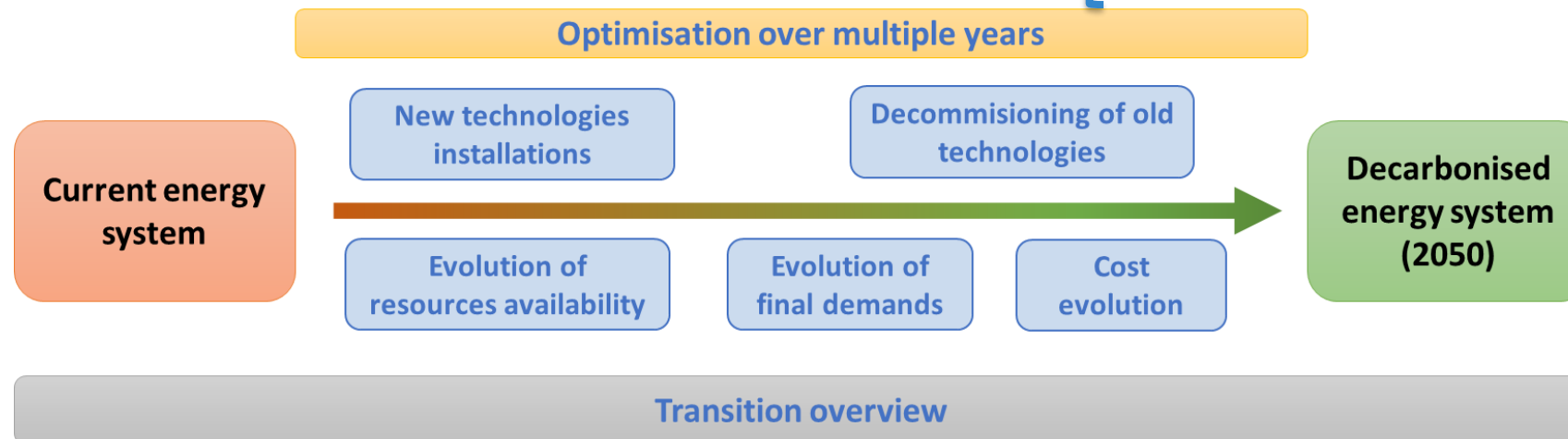
Simulation and optimization of the Italian national energy system:

- **long-term scenarios at low- or net-zero CO₂ emissions**
- **defining the role of hydrogen** and related infrastructures in the national energy system

Model Multi⁴

- Multi-vector
- Multi-node
- Multi-sector
- **Multi-period**

- Electricity (EE)
- Hydrogen (H₂)
- CH₄-H₂ blends
- Liquid fuels (LF)
- Regional description of the country (20 regions)
- Power sector
- Civil
- Industrial
- Mobility
- Understand how energy system **evolves** and adapts over time
- Verify **feasibility** of snapshot analysis
- Optimise investments **through the years** with a long-term view
- Assess the respect of CO₂ budget and intermediate targets



Developed

OMNI-ES

Framework

- Proprietary relying on Matlab

Multi-vector

- Electricity (EE)
- Hydrogen (H₂)
- CH₄-H₂ blends
- Liquid fuels (LF)

Multi-node

- Regional description of the country (20 regions)

Multi-sector

- Power Sector
- Heating and Cooling
- Civil
- Industrial
- Mobility
- Perfect foresight approach

Multiple Models

Advanced
Status

Oemof snapshot

Framework

- Oemof snapshot

Multi-vector

- Electricity (EE)
- Hydrogen (H₂)
- CH₄-H₂ blends
- Liquid fuels (LF)

Multi-node

- Regional description of the country (20 regions)

Multi-sector

- Power Sector
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- Mobility
- Perfect foresight approach

Work in
progress

Oemof Multi-Period

Framework

- Oemof multi-period

Multi-vector

- Electricity (EE)
- Hydrogen (H₂)
- CH₄-H₂ blends
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Multi-node

- Regional description of the country (20 regions)

Multi-sector

- Power Sector
- Heating and Cooling
- Civil
- Industrial
- Mobility

Multi-period

- Perfect foresight approach
- Time clustering (typical days and repeated years)

Colbertaldo P, Parolin F, Campanari S. A comprehensive multi-node multi-vector multi-sector modelling framework to investigate integrated energy systems and assess decarbonisation needs. Energy Convers Manag 2023



Research question and modelling needs

Not possible to use snapshot model since it is important to track the possibility to invest through the years

Multi-period run would create even larger computational burden

- Snapshot model already requires a big computational burden for 8760 hours
- Time clustering
- Issues in the storage sequences

Brief summary of changes in oemof for clustering

Input profiles

Pre Processing of
input profiles

Addition of clustering algorithm to group in clusters the timeseries required in input

Timeindex created according to the output of the clustering

Model.py

Addition of a
second hour-
related time scale

Which is not formed by the hours present in the timeindex but has 8760 h per each year simulated (the link in the operation is given by a relation derived from clustering), needed for the storage technologies

Generic_storage.py

Change in the
constraints

Change in the constraints to simulate each hour of the year instead of considering only the hours included in the timeindex

Addition of delta storage through years not simulated

Preliminary Results of clustering on snapshot model

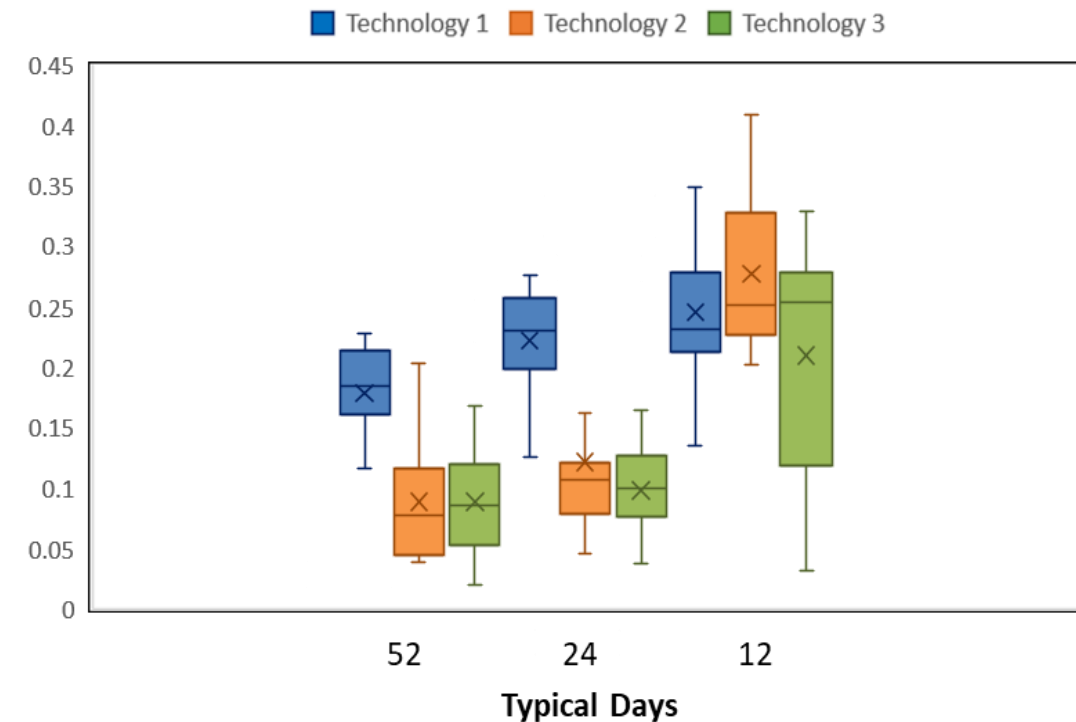
Number of typical days	Solution Time [minutes] **	RMSE DC Technology 1*	RMSE DC Technology 2 *	RMSE DC Technology 3*
12	8	Min: 0.349 Max: 0.135 Mean: 0.246	Min: 0.409 Max: 0.202 Mean: 0.277	Min: 0.330 Max: 0.032 Mean: 0.210
24	19	Min: 0.276 Max: 0.126 Mean: 0.222	Min: 0.320 Max: 0.046 Mean: 0.121	Min: 0.165 Max: 0.038 Mean: 0.098
52	58	Min: 0.227 Max: 0.032 Mean: 0.178	Min: 0.234 Max: 0.039 Mean: 0.089	Min: 0.168 Max: 0.020 Mean: 0.089
365	Out of memory 124 minutes on a different computer (on a working station with RAM of 64 GB)	No ERROR	No ERROR	No ERROR

*Minimum, Maximum and Mean Values among the technology error of each region

**Simulation done with RAM of 16 GB and Processor Intel Core i7

Error Definition
$$RMSE = \sqrt{\sum_{i=1}^n \frac{(y_i - x_i)^2}{n}}$$

RMSE on the Duration Curve for each storage technology



*Thank you for the
attention!*

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Name	Main scope	Features	Status	Papers and <u>publications</u>
NEMESI	Define the Italian strategic energy plan	8760 timesteps, 1 node, high technological detail	Concluded	F. Fattori, L. Tagliabue, G. Cassetti, M. Motta, "Enhancing power system flexibility through district heating - potential role in the Italian decarbonisation", 2019 IEEE International Conference on Environment and Electrical Engineering (EEEIC), Genoa, Italy, June 2019
HOT-SPOT	Define the Italian district heating potential	Fine geographical detail and high technological detail	Concluded	Spirito, G.; Dénarié, A.; Fattori, F.; Motta, M.; Macchi, S.; Persson, U., "Potential Diffusion of Renewables-Based DH Assessment through Clustering and Mapping: A Case Study in Milano", Energies 2021 Dénarié, A., Macchi, S., Fattori, F., Spirito, G., Motta, M., & Persson, U. "A validated method to assess the network length and the heat distribution costs of potential district heating systems in Italy." International Journal of Sustainable Energy Planning and Management, 2021, 31, 59–78
PREAC	Define the strategic energy plan of Lombardia	Very high technological detail and fine geographical detail (17 zones), 1 timestep	Concluded	M. Pozzi, G. Muliere, F. Mezzera, F. Fattori, A. Dénarié, M. Motta, L. Mazzarella, «Decarbonization of the heating sector from a system point of view: the case study of the Lombardy Region», 77 th ATI National Congress, Bari, Sept 2022 F. Mezzera, G. Muliere, M. Pozzi, F. Fattori, L.A. Cassetti, M. Motta, "Evaluating the value of photovoltaics in decarbonization scenarios: evidence from the Lombardy Region ", 36 th ECOS conference, Las Palmas de Gran Canaria, June 2023
NEMESI-R	Collaborate to the Italian strategic energy plan	8760 timesteps, 20 nodes, high technological detail	Advanced Status	