PhD course in Energy, Systems, Territory and Constructions Engineering - XXXVII cycle

MEASURING, ASSESSING AND IMPROVING ENERGY PERFORMANCE IN INDUSTRY

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1 RESEARCH PROBLEM

Measuring, assessing, and improving energy performance are three intertwined tasks for achieving energy efficiency targets in industry.

A cross-sectoral approach aims to identify the different prospects, challenges, and solutions that characterize non-energy-intensive, energy-consuming, and hard-to-abate sectors.

Bottom-up energy analyses must be conducted in relevant contexts to uncover potentials on a large scale.

MEASUREMENT	*Load profiles Indicators*
ASSESSMENT	*Benchmarking Mapping*
IMPROVEMENT	*Selection Optimization*

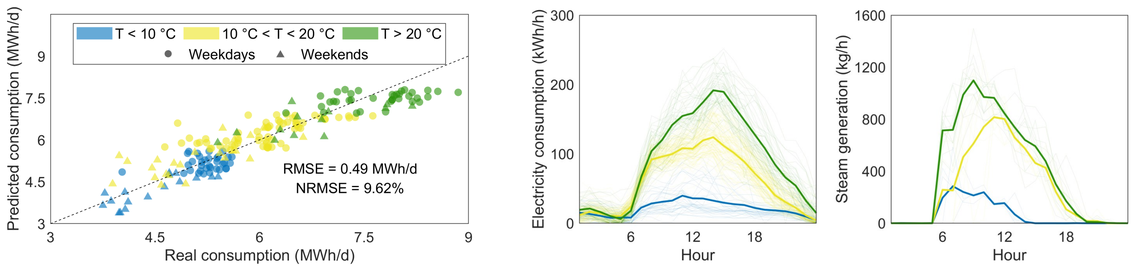
Non-energy-intensive **AGRI** | *Energy-consuming* **FOOD** | *Hard-to-abate* **GLASS**

2 MEASURING ENERGY PERFORMANCE

LOAD PROFILES

Using multiple regression and cluster analysis, electricity consumption and steam generation profiles are predicted to within 10% accuracy at daily and hourly resolutions.

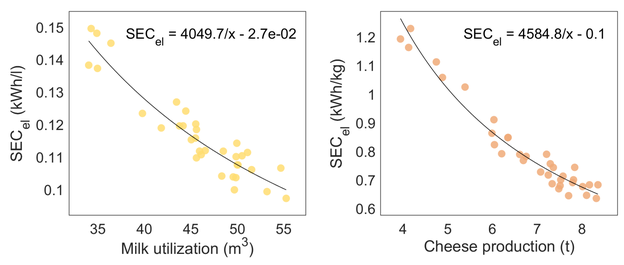
The identified patterns suggest the possible coupling of electric and thermal loads with renewable energy sources.



INDICATORS

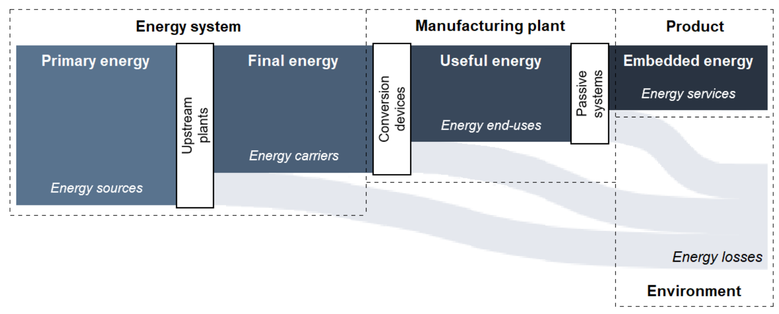
Electric indicators reveal interesting scale effects that can help identify inefficient operational regimes.

Thermal indicators and climatic influence require further research.



3 ASSESSING ENERGY PERFORMANCE

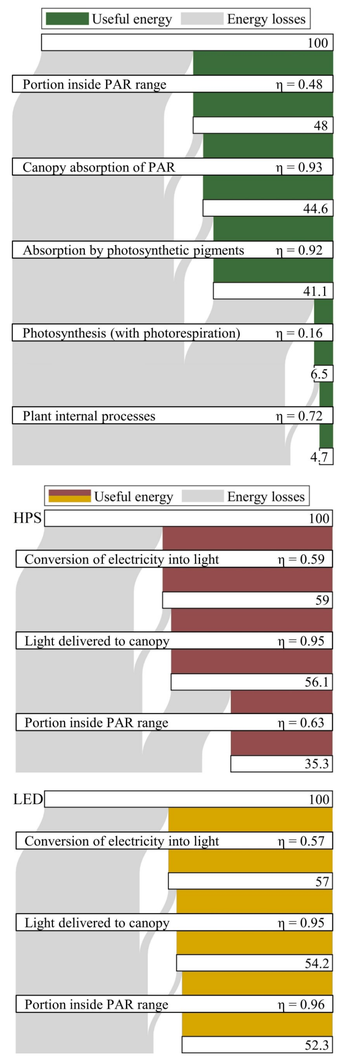
Mapping energy flows along the energy chain allows to consider energy losses in the systems involved, and the economic and environmental impacts.



MAPPING

The analysis of conversion efficiencies enables the comparison between traditional agricultural techniques and vertical farming.

LEDs performance is comparable with that of sunlight and may be further enhanced to approach current biological limits of photosynthesis.



4 IMPROVING ENERGY PERFORMANCE

SELECTION

For hard-to-abate sectors, the number of available measures is limited and a robust energy analysis for each context is not available.

Promising options are analyzed through simple yet powerful energy balances to outline the most appropriate pathways.

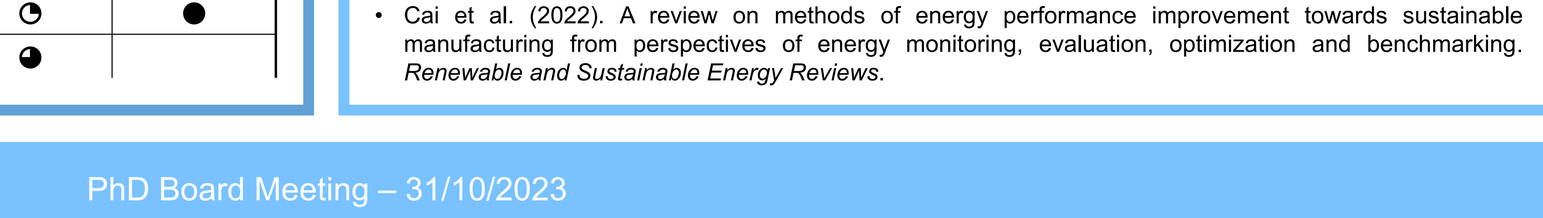
$$e_{emb} = \Delta h_R + c_{p,gl}(T_R - T_{in}) + bc_{p,gas}(T_R - T_{in})$$

$$e_{use} = \left[e_{emb} + \frac{\int UA(T_R - T_{in})dt}{\int m_{gl}dt}\right]\left[1 + \frac{(1+AFR)c_{p,fg}T_R - (c_{p,f} + AFRc_{p,a})T_{in}}{LHV_f - (1+AFR)c_{p,fg}T_R - (c_{p,f} + AFRc_{p,a})T_{in}}\right]$$

$$e_{fin} = e_{use}\frac{LHV_f - (1+AFR)c_p(T_R - T_{in})}{LHV_f - \left(\frac{1+\lambda AFR}{\eta_C}\right)c_p(T_R - T_{in})} = \left[e_{emb} + \frac{\int UA(T_R - T_{in})dt}{\int m_{gl}dt}\right]\left[\frac{LHV_f}{LHV_f - c_p(1+\lambda AFR)\frac{1}{\eta_C}(T_R - T_{in})}\right]$$

OPTIMIZATION

In the context of multi-objective optimization, assigning a penalty to the gap with best practice shifts the optimal solution towards 25% reductions in energy consumption.



5 FUTURE WORK

- Completion of the combinations of tasks and sectors
- Synthesis and review work for in-depth analysis of task and sectoral characteristics
- Focus on innovation in process energy requirements

	MEASUREMENT		ASSESSMENT		IMPROVEMENT	
	LP	IND	BEN	MAP	SEL	OPT
AGRI	◑	●	◔	●	◔	◔
FOOD	●	●	◔	●	◔	●
GLASS		◑	◑	◑	◕	

PUBLICATIONS

- Miserocchi L, Franco A, Testi D. An integrated framework for energy performance improvement in manufacturing: From mapping to optimization. *Journal of Cleaner Production*.
- Miserocchi L, Franco A, Testi D. Assessing Operational Variability in Food Factories: Implications for the Energy Performance of a Dairy Plant. *18th SDEWES Conference.*
- Franco A, Miserocchi L. Measuring Energy Use in Controlled Environment Agriculture. *MetroAgriFor 2023.*

REFERENCES

- Ibn Batouta et al. (2023). Energy efficiency in the manufacturing industry — A tertiary review and a conceptual knowledge-based framework. *Energy Reports.*
- Cai et al. (2022). A review on methods of energy performance improvement towards sustainable manufacturing from perspectives of energy monitoring, evaluation, optimization and benchmarking. *Renewable and Sustainable Energy Reviews.*