PhD in ENERGETICS

Research Title: Advanced Management for Resilient and Sustainable Multi-Energy Systems

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Supervisor	PhD Elisa Guelpa, elisa.guelpa@polito.it Prof. Vittorio Verda, vittorio verda@polito.it

Contact	

Context of the research activity	According to IRENA reports, creating a climate-proof society requires $110 trillion of investment in the energy sector by 2050. The smart interconnection of the energy infrastructures (i.e. production, conversion, transmission and storage technologies) is among the crucial actions to reach rational use of energy and the exploitation renewable or waste energy sources. Nowadays, the main research trends in this area concern the use of decision-making tools for the smart and optimised design/management of energy systems. Considering the management of a cogeneration unit as the benchmark, optimization allows economic savings between 10 to 20%, depending on the case considered. In case of districts supplied using a multi-energy system, savings can be further improved. In the context of multi-energy energy systems, there are significant opportunities and challenges to be faced. First of all, the management of integrated energy systems is becoming increasingly complex due to the requirements, mainly associated with decarbonisation. In particular, the road towards very high exploitation of renewable/waste energy sources is forcing the integration of multiple devices in case-dependent configurations/design/operation. In addition, renewable energy sources are inherently intermittent, so supply and demand must be properly

	managed, as using energy storage systems. Different types of storages are currently under investigation (e.g. electrochemical, chemical, mechanical, electrical and thermal). These components make it necessary to consider proper timeframes in the optimization, generally spanning over various days. Another crucial point is that optimal operations are affected by uncertainties, e.g. environmental conditions, energy/fuel prices, renewable energy production and power demands. At the same time, generation technologies are limited by technical constraints that should be taken into account to obtain realistic evaluations. In this context, a crucial challenge consists in developing an appropriate modelling framework able to include the technologies of the energy systems along with the energy networks (e.g. the electricity grid and the district heating and cooling network) and examine multiple and flexible scenarios.

Objectives	The objective consists in developing a multi-criteria decision-making tool for the management of multi-generation systems. More in details, this optimization tool should: a) be a comprehensive framework for the synthesis, design and operation of energy systems. b) include in the optimisation analysis different types of technically mature generation and conversion technologies (e.g. cogeneration units, gas and vapour compression heat pumps, solar collectors, storage systems, etc.), along with innovative technologies (e.g. biogas-fuelled micro-cogeneration units, phase change energy storages etc.). The latter might need the development of proper modelling approaches able to deal with the c) take into account for a potentially high number of variables in a integer-nonlinear problem, trough proper decomposition approach. d) include the contributions due to uncertainties in order to make the optimal or quasi-optimal decisions sufficiently robust to be economically and environmentally sustainable. A second objective consists in implementing the tool in at least one relevant case-study. The application will be selected taking advantage of the industrial collaborations of the research group, as indicated in the next section.

Skills and competencies for the development of the activity	In the last two years the research group have worked to develop an optimization tool for selecting the optimal scheduling of industrial multi-energy systems. The activity is developed within a research collaboration with the R&D section of a multinational company. This has led to a significant know-how in terms of issues and constraints, considered from the viewpoint of the operators. The research group has also worked for various years on the optimization of district heating systems, district cooling systems and thermal storage systems. The expertise developed in these areas, (e.g. design and modelling of generation/transformation technologies, heat network modelling and techniques to improve operations), proven by several papers published (>40), can be exploited for the analysis of the complex systems described above. Specific competences: - Knowledge on the development of optimization codes. - Modelling of technologies for energy production and conversion. - Network modelling. - Design and analysis of thermal energy storage.