Full Professor, PhD

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Short Bio

Massimiliano Renzi is Full Professor with fixed term contract (Endowed Professorship, Professore Straordinario) for Fluid Machine and Energy systems at the Free University of Bozen-Bolzano; he is the director of the Bachelor Course in Industrial Mechanical Engineering and director of the Research Macroarea in Energy Resources and Energy Efficiency (ERE2). He is also member of the Competence Center of Sustainability.

He received his Master Degree in Mechanical Engineering magna cum laude in 2007 and his PhD in Energy in 2011 from the Polytechnic University of Marche. In 2009 he started his collaboration with a University spin-off, Strategie srl, working in the field of energy conversion and innovative energy systems. He is also shareholder of the company and owns two patents on the tracking device for solar concentration systems.

He is in charge of several research projects funded with competitive peer review processes and he manages research and didactic activities in the field of Fluid Machines and Energy Systems at the Free University of Bozen-Bolzano.

The main research topics include: use of alternative green fuels, like hydrogen, ammonia, biofuels and producer gas, and novel combustion strategies in the hard-to-abate industrial and civil sectors; hydraulic machines for small- and hidden hydropower and pumped hydro storage; use of batteries in automotive, industrial and grid applications, thermal management of powertrains with specific focus on thermal engines and battery systems for clean powertrains; decarbonization of the power sector; novel optimization strategies and algorithms for sustainable energy planning of hybrid energy systems and energy storage solutions using MILP and AI algorithms.

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Keywords

Fluid Machines and Energy Systems

Hydrogen technologies and storage

Hydropower, Pump-as-Turbines

Batteries for automotive, industrial, and grid applications

Clean powertrains for green mobility

Combustion of green fuels

Power generation and smart grids

MILP and IA techniques for Energy Systems and Energy storage optimization

Main Research Activities and Labs

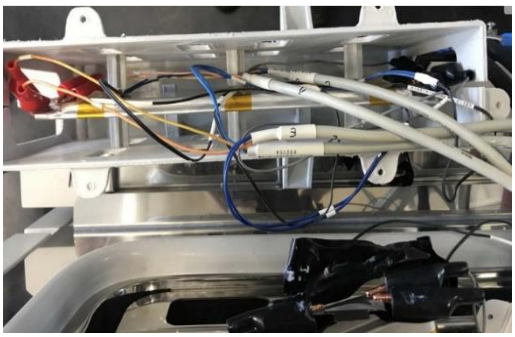
HYDROGEN TECHNOLOGIES – The hydrogen energy vector is studied in a comprehensive way, considering the main technologies that are required for its production from green energy, its storage and its final use in fuel cells and in combustion processes. The laboratories include lab scale systems that are analysed to optimize their operation on the basis of the green energy availability and power demand; novel storage solutions based on metal hydrates are studied in combination with their thermal management. Hydrogen and ammonia are also studied as green fuels for the thermal power demand in the hard-to-abate sectors. Optimization codes are also developed to identify the optimal sizing and management of the energy chain, also using data-driven methodologies and neural networks.

Hydrogen test bench (eletrolizer, fuel cell, metal hydrates)

GREEN POWER GENERATION – Different cogeneration devices are studied with a specific focus on the use of alternative fuels and the application of innovative power cycles. The performance and the emissions of engines can be assessed with specific test benches, specifically studied for different applications, like cogeneration and engines for agricultural applications. A specific focus is also dedicated to the analysis of hydrogen and green fuels: a test bench for the combustion analysis is available and optical measurements are adopted to analyze the combustion stability, performance and emissions. Also CFD simulations are developed to study the combustion process with biofuels and hydrogenated fuels. Novel design solutions for combustors are developed for specific power generation applications.

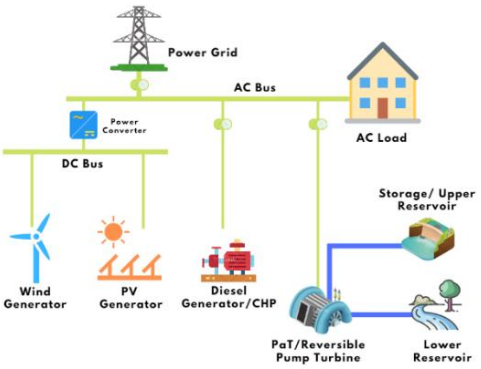
Combustion test bench for green fuels

ELECTRIC AND HYBRID POWERTRAINS – This research topic aims at studying the energy flows in hybrid and electric powertrains with the primary objective of reducing the environmental impact and increasing the performance of the powertrain. One of the research goals aims at optimizing the design of lithium-ion batteries in order to improve the thermal homogeneity and the battery life and performance. A detailed model of the electric and thermal characteristic of the cell and of the module has been developed to forecast the behaviour of the battery and to design the required cooling system. Both experimental tests and CFD simulations have been carried out. In a second research focus, the optimal electrification strategies of tractor engines and agricultural machines is studied. Specifically, a comprehensive model of the power flows of the tractor is developed and the analysis of the emission reduction potential is evaluated by analyzing the electrification potential of the implements and of the auxiliary systems within a tractor powertrain.



Lithium-ion cell electric and thermal tests for electric vehicles

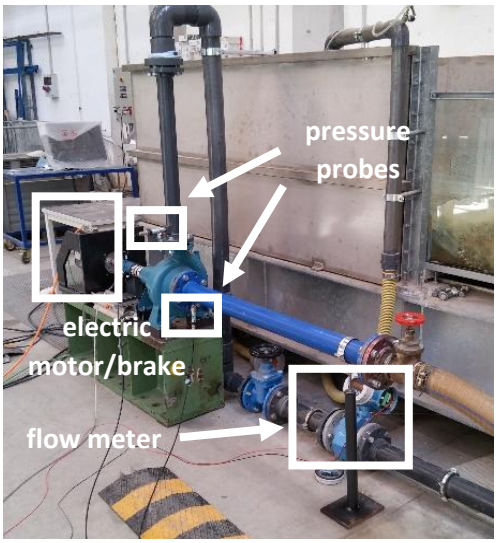
OPTIMIZATION OF HYBRID ENERGY SYSTEMS WITH STORAGE – Optimization techniques are studied for the optimal design and management of hybrid networks powered by renewable sources and micro-CHP systems. The optimal sizing and management of the power generation devices is fundamental to increase the penetration of renewable resources in the electric system and for the development of smart grids. The intermittent availability of renewables requires an optimal management with storage solutions, like batteries, hydrogen vector and pumped hydro. Advanced optimization techniques are studied and developed together with models of different power generation devices. Specifically, Mixed Integer Linear Programming techniques and codes are used to identify the optimal management of power generation systems and to minimize cost function, like harmful emissions and the cost of production of energy. Also data-driven techniques and AI solutions are employed for the prediction of the management of smart grids.



Modelling and optimization of hybrid energy systems and storage solution

HYDROPOWER – This research line aims at the development of novel solutions for energy recovery solutions with hydraulic machines in civil and industrial plants, as well as the study of mini and micro hydroelectric plants. Innovative design solutions are studied to adopt low-cost machines and to widen their operating range in energy recovery solutions and mini hydropower.

The labs are equipped with test benches for the analysis of the performance of hydraulic machines and the definition of hill diagrams of test scale machines. Also a detailed analysis of the fluid-dynamic behaviour of these machines is possible thanks to the use of optical, non-intrusive measurement techniques. Novel methodologies, also based on artificial neural networks, have been developed to forecast the performance of the machines and to provide an accurate design tool and to describe machine performance in design and in off-design working conditions. Fluid dynamics simulations with CFD software are also performed to predict performance and optimize the design.



PaTs test bench

MAIN RESEARCH GRANTS AS PI OR CO-I

- **EFRE/FESR "Green Power Technologies Laboratory", project Lab-GPT (Principal Investigator, 2025, EU fund for regional develop. € 992'192,00).** The Lab-GPT project aims at developing a novel laboratory to study the main energy storage technologies and energy vectors that are supporting the deployment of renewable energies, smart grids and clean mobility powertrains. Specifically, the laboratory allows to test the management and the performance of the main hydrogen technologies (electrolyzers, fuel cells and storage) with a focus on novel storage solutions, like metal hydrates. In addition, the lab will embed cyclers to test in details the electric and thermal behaviour of battery cells used in the automotive sector, for the grid stabilization, and in novel applications; it is possible to test and develop specific BMS and thermal management solutions also for novel chemistries and materials.

- **EFRE/FESR "Sistemi di riscaldamento sostenibili per la decarbonizzazione degli edifici", project SustainHeat (Principal Investigator for the workgroup of the Free University of Bolzano, 2023, EU fund regional develop. € 1'120'007,84; € 318'179 for unibz).** The SustainHEAT project aims to contribute to the decarbonisation of buildings by intervening on heating systems. In the project, test procedures will be developed to characterise performance by evaluating the influence of predictive control logics. The impacts of sustainable heating systems will be assessed in terms of energy efficiency, flexibility for district heating and electricity grids, and environmental impact. As a further objective, the project aims to update the training paths for planners and installers by providing a dimensioning tool for sustainable heating systems and using workshops for knowledge transfer. The laboratory training will include simple monitoring systems that they can replicate in their daily work.
- **Province call for research 2023, Autonomous Province of Bolzano, project ReNoN: Total energy integration of Renewable-based Networks of Networks towards a decarbonized infrastructure (Principal Investigator for the workgroup of the Free University of Bolzano; grant for unibz € 147'500).** The goal of the project is to produce a tool for energy policy makers and energy managers based upon numerical optimization techniques, with a novel two-level architecture. The first-level will be in charge of skimming the available local distributed resources that can provide a service given the specific environmental, technical and economic boundary conditions; this part of the algorithm will also identify the most critical performance parameters (KPIs) and optimization goals of the ReNoN, given the technical, economic and environmental boundary conditions. The second level optimization, computes the optimal management solution of the ReNoN (e.g., minimization of emissions, keeping system efficiency above a threshold, ensuring continuity of service according to a certain order of merit, stability of the grid, overall energy cost minimization, etc.) by considering the specific digital-twin models of the technologies involved. This lower-level algorithm can be also updated on-line with data coming from energy flow sensors, actual environmental conditions, resources availability to manage future interconnected smart-cities.
- **Province call for research 2014, Autonomous Province of Bolzano, project AI-ALPEN: Supply of drinking water in alpine regions: piping loss reduction and energy optimization for long-term sustainability (Principal Investigator for the workgroup of the Free University of Bolzano; grant for Bolzano € 148'703)** This project is made in collaboration with the Department of Hydraulics of the University of Trento. The purpose of the project is to define appropriate methodologies for the characterization of the water network losses and ensure the optimum utilization of the power production potential in water supply systems. A specific test bench has been used together with numerical CFD simulation tools for the description of the performance of hydraulic turbines (or Pump as turbines) that can be inserted into the water networks for energy recovery purposes.
- **Project "Hydraulic energy recovery strategies for future green water supply systems (HYDE) founded by the Italian Ministry of Research PRIN (Progetto di Ricerca di Interesse Nazionale, grant for Bolzano € 67'284).** The energy optimization of water distribution, treatment and pressure regulation will be addressed, by also considering the fluctuating nature of the flows in water supply systems, while preserving customer demand. The project will also tackle the challenges of complex control, off-design operation and instabilities that can limit the application of energy recovery machines, like pump-as-turbines, as well as techniques to detect the health state to propose a smart management of the WSSs. The hydraulic machines will be tested experimentally and novel design solutions will be proposed to widen the operating range and facilitate the flow and pressure control in WSSs, by also considering the possibility to use variable speed drives.
- **Organic Rankine Cycle as REVersible Energy Recovery systems for industrial applications (REVER), founded by the Italian Ministry of Research PRIN (Progetto di Ricerca di Interesse Nazionale, grant for Bolzano € 59'099).** The aim of the project is to analyse and develop low-cost Organic Rankine Cycle based reversible technology. It is all-in-one device capable to alternatively supply end-users with the respective electric, or upgraded heating powers in the small and mid scale by exploiting low temperature industrial waste heat. REVER will efficiently provide the end-users

with electricity or upgraded heat thanks to its large flexibility, as it is capable to chase and satisfy the end-users energy requirements Therefore by combing advanced numerical and computational simulations with extensive experimental tests the project aims at reaching breakthrough results in the field.

- **Project "Design of more-electric tractors for a more sustainable agriculture" GREEN-SEED, founded by the Italian Ministry of Research PRIN (Progetto di Ricerca di Interesse Nazionale, grant for Bolzano € 102'000)**: PI of the work unit of unibz for the national PRIN project. This project aims to create the background, currently missing, to face the design of a complete more electric tractor system, identifying, among the others, the best electrification structure topology to be adopted, the load requirement for different operations and the components currently used that need to be redesigned. These further steps could be implemented in a larger project with the objective to design and build a real scale prototype of more-electric tractor involving more partners also in the frame of EU project, since the topic is within the priorities of the European Agency for Horizon 2020 about sustainable growth, in the Flagship Initiative "Resource efficient Europe".
- **Project "Thermal management of the accumulator batteries in electric and hybrid cars: optimization strategies for performance enhancing and for a sustainable mobility" (2017, EU fund regional develop. 874.038 €);** In collaboration with Roechling Automotive AG. The purpose of this project is to study and optimize the thermal and energy flows of the car system with the primary objective of reducing the environmental impact, increasing the performance of accumulators. New innovative solutions for the battery pack cooling system of the electric vehicles, as well as for the powertrain thermal management will be proposed; in parallel, a numerical analysis will be carried out, using simulation software, in order to evaluate the possible optimization strategies in the management and control of the flows of refrigerant liquids within the battery pack.
- **Project "Turbine Idrocinetiche, ottimizzazione per una produzione sostenibile" (2017, EU fund regional develop. 884'600 €);** in collaboration with the local companies Troyer and AC-TEC. The project has the aim to develop, together with companies working on hydro turbines production, research activities for improvement of conventional and original hydro power turbines (mini-hydro). The research activities will include both Computational Fluid Dynamics studies and analyses on physical models of innovative solutions for mini hydro. The research results that will be obtained during the project, will not be solely submitted for publishing on scientific journals, but also "engineered" and applied to partner manufacturing machines. Therefore, this should enable to improve the competitiveness of the products of the industrial partners and to acquire new market shares.
- **Several internal projects of the Free University of Bozen/Bolzano on cogeneration systems and smart energy systems**: "Design and study of the performance of a microcogeneration system using internal combustion engine fuelled by intermediate fuels from biomasses"; "Indirect energy efficiency and torque assessment of internal combustion engines based on exhaust gas temperature and O2 content" and "Direct evaluation of the performance of internal combustion engines with the measurement of the indicated thermodynamic cycle"; "Cogeneration system fed by solid fuels´ synthesis producer gas" and "Experimental measurement system of the heat recovered by micro cogeneration systems"; "Study of the combustion and of the engine management strategy of a dual fuel internal combustion engine fed with alternative fuels".

OTHER GRANTS AS PARTICIPANT

- **"Thermo Fluid Dynamics, infrastructures for applied research to business and industry in South Tyrol" (2016, EU fund for regional develop. 849.600 €).** The project involves the construction of a thermo-fluid dynamics laboratory in which test lines will be installed to test compressible fluids, incompressible fluids and combustion systems to be applied to the study of fluid machines. The laboratories are being set up in the NOI technology park. They will be provided with

the instrumentation for the advanced study of hydraulic machines (pumps and turbines) and compressible fluid machines, as well as cogeneration. In addition to traditional methodologies, optical measurement techniques will be applied to study the fluid dynamics of fluid machines, thermo-fluid dynamics, sprays and combustion (PIV, LDV, PDPA).

EXTERNAL COMPANIES' COMMISSIONED RESEARCH

- Research on the role of coal in the context of the Italian energy system: regulation and technologies for energy production and for pollutants' removal (Ottanatuno Group);
- Study of the SCR systems for the abatement of NOx emissions in the automotive sector (Röchling Automotive);
- Fluid dynamic simulation of a refill circuit of an AdBlue tank of a Selective Catalytic Reducion (SCR) system for the abatement of NOX emissions from the combustion in automotive diesel engines (Röchling Automotive);
- Fluid dynamic simulation of a Kaplan hydraulic machine (AC-TEC Caldaro);
- Fluid dynamic analysis of kitchen hoods (Revolt srl);
- Consultancy in the design of two-phase scroll expanders for energy recovery (Tifeo srl).

SUPERVISION

I have been supervising 14 PhD students at the Free University of Bozen/Bolzano on topics related to power generation with alternative green fuels, small-scale hydropower for energy recovery, optimization of energy systems, novel powertrains for clean mobility.

I am currently supervising three research assistant positions and an Assistant Professor. I also supervised several final thesis works at Bachelor and Master level.

PATENTS

I am co-inventor of three patents on systems for solar tracking used in concentration solar power applications (WO2014184815, ITAN20130093, ITAN20130092A1).

INTERNATIONAL JOURNAL PUBLICATIONS

I'm author of 167 scientific works: 98 articles in international journals, 62 international conferences, 7 in national conferences, 2 technical reports.
Scopus database: Number of records: 130; Number of citations: 2729; h-index: 32.

List of the International Journal publications:

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   Impact Factor: 3.356; Cite Score: 3.78.

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12. Prando D, *Renzi M*, Gasparella A, Baratieri M. **Monitoring of the energy performance of a district heating CHP plant based on biomass boiler and ORC generator**. *Applied thermal engineering*. 2015:79;98-107. DOI: 10.1016/j.applthermaleng.2014.12.063 Impact Factor: 3.356; Cite Score: 3.78.
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