

**Ph.D. in Information Technology
Thesis Defense**

**April 9th, 2025
at 14:00**

Room BIO1 – edificio 21

Mattia TIBALDI – XXXVII Cycle

Adaptive hardware for energy-efficient FPGA-based data centers

Supervisor: Prof. Christian Pilato

Abstract:

Modern applications require the elaboration of massive amounts of data. Due to the computational power needed, such applications may execute in data centers that consume immense energy. In 2024, data centers contributed to 2.18% of the carbon emissions, with an increasing trend. Major Data Center operators implement several techniques to improve the sustainability of their systems (e.g. solar panels, windmills, and/or nuclear reactors on premises). Nevertheless, it is still highly relevant to explore hardware and software solutions to optimize the energy efficiency. So, designers should guarantee a high quality of the result and efficiently manage the energy required by the computation to reduce costs and carbon production. Many data centers are moving towards heterogeneous architectures equipped with specialized hardware to achieve high performance and power savings. These architectures with the customization can significantly minimize energy consumption, while hardware parallelism can optimize the execution time.

However, such components have limited flexibility. Once designed, they cannot execute the functionality differently. Also, the energy consumption is fixed and depends on the implementation of the architecture. This research proposes implementing an adaptive system based on FPGA to guarantee flexibility, develop different versions of a computation component, and select the version at run time. In this way, based on the stimuli coming from the environment, such as the intensity of the incoming traffic, or availability of renewable energy, it will be possible to use logic with different energy profiles. This approach allows me to design accelerators with a power efficiency of 25× respect to a CPU and a 40% final reduction in carbon emissions.

PhD Committee

Prof. Cristina Silvano, **Politecnico di Milano**

Prof. Sara Vinco, **Politecnico di Torino**

Prof. Pedro Petersen Moura Trancoso, **Chalmers University of Technology**