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HABILITATION THESIS

- SUMMARY -

**Contributions to the energy efficiency of electrical and
electromagnetic systems: from bioengineering to smart buildings**

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Introduction. Professional Path and Research Activity

This thesis synthesizes the results of more than 22 years of the author's teaching and research activity. She is a graduate of the Faculty of Electrical Engineering of the Technical University of Cluj-Napoca (TUCN), holding a dual specialization (General Electrical Engineering, and Accounting and Management Information Systems, Babeş-Bolyai University), and a PhD completed in 2012 on the topic of functional magnetic stimulation of the spinal cord.

Her teaching career, carried out within the Department of Electrotechnics and Measurements, has progressed steadily - teaching assistant (2008–2013), lecturer (2013–2018), associate professor (since 2018) - covering disciplines such as Theory of Electric Circuits, Theory of the Electromagnetic Field, Electrical Engineering, and Numerical Modeling of Electric Circuits.

Her research activity has been carried out within the Research Center for Energy Transition (ENTREC) at TUCN. She is director of 5 national and international research contracts (including RENplusHOMES – Horizon Europe, grant 101103450, total budget EUR 5.99 million, EUR 463,187 for TUCN) and a member of 11 large-scale international contracts, including the Horizon 2020/Europe projects RE-COGNITION (grant 815301), DR-BoB (grant 696114), EVELIXIA (grant 101123238), OLGA (grant 101036871) and SMEmPower Efficiency (grant 847132), in addition to participation in 13 other national projects. The portfolio has recently expanded toward smart urban planning (COREspaces, Mobility Justice for All) and electric mobility (Ro-Green).

Her scientific output includes more than 120 published papers (37 indexed in ISI, 22 in BDI databases), including articles in IET Renewable Power Generation (Q1), COMPEL, IEEE Transactions on Magnetics, Artificial Organs, and Ceramics International (Q1, 2026), as well as six teaching/research books, two of them as first author, including recent volumes dedicated to energy communities.

Her contributions to research projects have been recognized through European distinctions (Best European Energy Service Project – European Commission, 2019; AEE Regional Award, 2018; Romanian Energy Award, 2015) and through IEEE membership, service as a reviewer for ISI journals (IET RPG, Energies, COMPEL, Sustainability, among others), and a visiting professor appointment at the University of Florida (2022).

The thesis is structured in six chapters: Chapter 1 presents the professional path; Chapters 2–5 detail the original scientific contributions, from fundamental electromagnetic modeling (Chapter 2), to energy flexibility and demand response (Chapter 3), to the cognitive automation of this flexibility through integrated renewable sources (Chapter 4), to the integrated design and renovation of buildings toward positive-energy building status (Chapter 5); Chapter 6 presents career development plans.

Design and Energy Optimization of Coils for Magnetic Stimulation of the Spinal Cord

This research, carried out during the postdoctoral fellowship (Programme POSDRU/159/1.5/S/137516) and published in *Artificial Organs* (2015) and *COMPEL* (2015), started from the experimental observation that the commercial magnetic stimulator Magstim Rapid² (“figure-of-eight” coil) fails to directly activate the neural tracts of the spinal cord, instead stimulating only the adjacent spinal nerves. The author modeled the electrical circuit of the stimulator (series RLC regime, oscillatory and aperiodic regimes), designed and calculated the coil parameters (geometry, inductance, resistance), and comparatively analyzed several alternative winding distribution configurations (disc and solenoidal, with uniform or graded axial layers), evaluating dissipated energy, magnetic energy, coil heating, and the required initial voltage.

The results showed that distributing the windings across multiple axial layers reduces the initial voltage required to activate the spinal cord by 25–30%, and reduces the energy consumed and coil heating per pulse by more than 22% and 24% respectively, compared with the commercial disc-type coil, opening the way toward a stimulator capable of repetitive-mode operation, which is required for motor rehabilitation. The methodology developed here (rigorous numerical modeling, experimental validation, optimization under multiple energy constraints) forms the methodological foundation carried forward into the subsequent chapters, dedicated to the energy management of buildings.

Demand Response in Building Clusters — the DR-BoB Project

Within the European DR-BoB project (Horizon 2020, grant 696114), TUCN served as the demonstration pilot site for Romania, alongside pilot sites in the United Kingdom, France, and Italy. The project aimed to reduce electricity demand by up to 35%, reduce peak consumption by up to 30%, and engage at least 25% of occupants in reducing energy consumption. The author was the technical lead for implementing the three Demand Response scenarios at the TUCN pilot site, for the methodology used to calculate the key performance indicators (KPIs, per deliverable D5.1), and for the user communication and engagement strategy.

Her own baseline-setting methodology combined ARIMA models with Local Energy Market-type methods, as well as clustering techniques (Kohonen SOM maps) and day-matching, later applied in the article published in *IET Renewable Power Generation* (Q1). The quantitative evaluation at the TUCN pilot site (comparing the Faculty of Electrical Engineering and the Swimming Pool Complex) showed primary energy savings of 1.257 GWh/year — the highest among the consortium's four pilot sites — an Internal Rate of Return exceeding 20%, and a payback period of 4.5 years, demonstrating the technical and economic feasibility of the solution even in the absence of a national flexibility-services market. The experience gained in occupant communication and engagement remained a methodological reference for the subsequent projects, RE-COGNITION, RENplusHOMES, and EVELIXIA.

Optimization and Forecasting Algorithms for Energy Management — the RE-COGNITION Project

Within the Horizon 2020 RE-COGNITION project (grant 815301), the author contributed along three directions: the mathematical foundation and experimental validation of forecasting and optimization algorithms; the development of two key platform technologies — ACEME (Automated Cognitive Energy Management Engine), a multi-agent architecture

based on a MILP-type optimization model for the Optimal Dispatch Agent, and BE-PLATO (Building Energy-Planning Tool for Optimal Solutions), a planning tool for optimal sizing of renewable-source installations, featuring an economic model (NPV, PBP, LCC) and the COBYLA optimization algorithm; and the coordination of experimental validation and the user communication strategy.

The consumption- and photovoltaic-production forecasting algorithms were selected and comparatively validated from a set that included ARIMA, MILP, XGBoost, LightGBM, CatBoost, and LSTM. The solution was implemented at the TUCN demonstration site, the Swimming Pool Complex, through the installation of a building-integrated photovoltaic (BIPV) system and an electric vehicle (EV) charging station, and was validated both on a laboratory test-bed platform (1:6 time scaling) and under real operating conditions over a two-month period, including an unforeseen-event adaptability scenario and an EV charging-management scenario.

The results confirm the technical feasibility of the solution and provide a foundation for extending the approach to building clusters and for integration with energy flexibility markets.

Transition to Positive-Energy Buildings — the RENplusHOMES Project

In the Horizon Europe RENplusHOMES project (grant 101103450), the author is project director on behalf of TUCN, responsible for one of the consortium's four demonstration sites. The TUCN pilot site is a student dormitory in the Mărăști campus, with a surface area of 8,054 m² and 240 rooms. This chapter describes the reference building (natural-gas heating, domestic hot water), the proposed renovation scenario, the Geothermal Wall solution, and a building-integrated photovoltaic (BIPV) system using recycled cells, along with the results of the dynamic energy simulations.

The renovation scenario, at the demonstrated scale, generates a 7.06% reduction in life-cycle primary energy consumption, a 6.28% reduction in greenhouse gas emissions, and a 6.57% reduction in total life-cycle costs. The chapter also includes an assessment of the pathway toward “positive-energy” building status, the trajectory for expanding renewable-source capacity across the entire building, and a technical NetZero/Positive Energy sizing scenario for the Mărăști campus, together with the recommended priority measures.

As project director, the author coordinated data acquisition and validation, calibration of the simulation models, institutional representation within the consortium, and the development of the expansion strategy submitted to TUCN's management.

Career Development Plans

The professional development plan is structured across three time horizons: short term (1–3 years): completing and capitalizing on ongoing Horizon Europe projects and updating teaching materials; medium term (3–5 years): obtaining PhD supervisor status, coordinating new research projects, and strengthening international collaborations; long term (5–10 years): developing an independent research direction, recognized nationally and internationally, at the interface between building energy efficiency, renewable source integration, and smart energy communities.

Future research directions include: advanced building energy modeling using artificial intelligence techniques; electric mobility and Vehicle-to-Grid (V2G) integration; thermal energy storage using phase-change materials (PCM); IoT monitoring and digital-twin platforms for buildings; energy communities and the regulatory framework; smart urban planning and sustainable mobility; and the development of proprietary software tools.

Complementary plans concern: modernizing teaching materials and internationalizing the course offering; attracting research funding and training young researchers, alongside obtaining PhD supervisor status; disseminating results and expanding international collaborations; and institutional involvement through the ENTREC Research Center, academic leadership structures, and technology transfer to the socio-economic environment.

Conclusions

The habilitation thesis outlines a coherent and cumulative path, from the electrical-engineering foundations of numerical modeling applied to bioengineering, to the management of building energy flexibility through large-scale European projects (DR-BoB, RE-COGNITION, RENplusHOMES), highlighting both the original scientific contributions — forecasting and optimization algorithms, performance-indicator calculation methodologies, experimentally validated energy-renovation models — and the author's capacity to coordinate international research teams and projects, with results applied directly at the pilot sites of the Technical University of Cluj-Napoca.