Capacity building in Smart and Innovative eNERGY

WP4
Mutual Exchange of Personnel and Early Stage Researcher Involvement

# D4.4 Updated Report on Early Stage Researcher Engagement and Mentoring

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# Executive Summary

This document follows the work outlined in the task T4.3 entitled *Engagement of (Institute Mihajlo Pupin) IMP's early stage researchers*. As envisioned in the SINERGY description of work, besides IMP staff, young researchers from partner institutions (AIT - Austrian Institute of Technology and NUIG - National University of Ireland, Galway) have been involved in all SINERGY activities (e.g. trainings, Ph.D. Workshops, the SINERGY International Conference) and hence their joint work is reported within this report, as well.

Building upon

- the D4.3 Report on Early Stage Researcher Engagement and Mentoring; and
- WP5 deliverables (D5.1 The First SINERGY Workshop – Smart Grid Technologies, D5.2 The Second SINERGY Workshop – Energy Efficient Building Operation, D5.3 The Third SINERGY Workshop – Belgrade's Smart Energy Management laboratory, D5.4 International SINERGY Conference on Smart Energy Management Technologies;

this deliverable is structured by the effort taken and results achieved by each partner, as follows:

- Section 2 presents an overview of the main events organized for the early-stage researchers (Ph.D. Workshops, the SINERGY International Conference) in the whole project framework;
- Section 3, Section 4 and Section 5 introduce the results of IMP, AIT and NUIG early stage researchers subsequently;
- Section 6 closes the deliverable.

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## Abbreviations and Acronyms

| | |
|---|---|
| **AIT** | Austrian Institute of Technology |
| **BSPs** | Balancing Service Providers |
| **CA** | Consortium Agreement |
| **CNN** | Convolution Neural Network |
| **CO** | Coordinator |
| **DSO** | Distribution System Operator |
| **EMS** | Energy Management System |
| **ERDF** | European Regional Development Fund |
| **EU** | European Union |
| GUs | Generation Units |
| **GDPR** | General Data Protection Regulation |
| **HRES** | Hybrid Renewable Energy Systems |
| **IEEE** | Institute of Electrical and Electronics Engineers |
| **ICT** | Information and Communications Technology |
| **IMP** | Institute Mihajlo Pupin |
| **KG** | Knowledge Graph |
| **LSTM** | Long Short-Term Memory |
| **LV** | Low Voltage |
| **NILM** | Nonintrusive Load Monitoring |
| **NUIG** | University of Galway |
| **PV** | Photovoltaic |
| **RSCs** | Regional Security Centres |
| **REC** | Renewable Energy Communities |
| **RES** | Renewable Energy Sources |
| **RML** | RDF Mapping Language |
| **R&D** | Research and Development |
| **SCADA** | Supervisory control and data acquisition |
| **SGAM** | Smart Grid Architecture Model |
| **TSOs** | Transmission Service Operators |
| **WP** | Work Package |

# 1 Introduction

The main scope of work package 4 (Mutual exchange of personal and early stage researcher involvement) can be summarized as:

- Task 4.1: Hosting of distinguished foreign researchers (for training lectures);
- Task 4.2: Organization of short-term and long-term stays (for all Sinergy staff);
- Task 4.3: Engagement of IMP's early stage researchers (to involve young researchers in projects).

WP4 activities address the Objective 2 of the SINERGY Project entitled **Reinforcement of scientific and technology excellence of the linked institutions in domain of Smart energy management.**

This document follows the work outlined in the corresponding task T4.3 titled Engagement of IMP's early stage researchers. As envisioned in the SINERGY description of work, young researchers from partner institutions (Institute Mihajlo Pupin, Austrian Institute of Technology and National University of Ireland, Galway) have been involved in all SINERGY activities and hence their joint work is reported within this report.

## 1.1 Relation to D4.3

The Task 4.3 activities for the first reporting period (January 2021 – March 2022) were reported in Deliverable 4.3.

The activities described in D4.3 continued in the second reporting period, i.e.

- Research and prototyping of innovative services on topics such as
  - Energy conservation measures service; Energy Efficiency User Benchmarking service; Energy-related forecasting; Grid capacity management service; Hardware-in-the-loop testing; Multi-agent distributed energy optimization; Integrated platform for demand response management;
  - Thermal building modelling; Validation of demand response management platform.
- Mentoring of young researchers and presentations/papers preparation;
- Organization of online and on-site pieces of training, as well as
- Organization of other staff exchange events (visits of the pilot facilities, discussions with engineers involved in commercial projects).

## 1.2 Structure of the Deliverable 4.4

The focus of this deliverable will be on results presented at events organized in the second reporting period (April 2022 – December 2023) i.e. the The Third SINERGY Workshop – Belgrade's Smart Energy Management laboratory and the International SINERGY Conference on Smart Energy Management Technologies, see Section 2. Indeed, these events were opportunities where researchers can schedule the next activities. Hence, Section 3, Section 4 and Section 5 point to the involvement of early-stage researchers from IMP, AIT and NUIG subsequently.

# 2 Joint Events aimed for Early Stage Researchers

## 2.1 First Reporting Period (Summary)

The following actions were undertaken for better involvement of young Ph.D. students:

- Preparation of a matchmaking Table of Ph.D. topics interesting for young researchers (please check D4.3, as well), assignment of mentors for the IMP researchers;
- Preparation of a summary of joint services development engagement, see topics below;
- Organization of Ph.D. Workshops (online), as follows
  - Ph.D. Workshop at the Belgrade BDA Summer School, https://project-lambda.org/Ph.D.-Workshop-2021, 1st reporting period;
  - Ph.D. Workshop during the 1st SINERGY Workshop, please check D5.1 and https://project-sinergy.org/Events/1st-Workshop, 1st reporting period;

**Table 1. Topics of joint piloting activities (see D4.3, March 2022)**

| | Partners | Topics |
|---|---|---|
| **(1)** | AIT and IMP | Energy conservation measures service<br>Energy Efficiency User Benchmarking service<br>Energy-related forecasting<br>Grid capacity management service<br>Hardware-in-the-loop testing<br>Multi-agent distributed energy optimization<br>Integrated platform for demand response management<br>Power electronics conversion for renewable energy generation and storage |
| **(2)** | NUIG and IMP | Thermal building modelling<br>Validation of demand response management platform |

## 2.2 Second Reporting Period (Summary)

In the second reporting period, two Ph.D. workshops were organized

- the 2nd SINERGY Workshop was organized from 31st of May until 2nd of June at the National University of Ireland Galway. More about the event can be found in D5.2;
- the 3rd SINERGY Workshop was an opportunity to check the status of the advancement of the career of young researchers toward the Doctoral degree and to plan the 3rd year SINERGY activities, including the final Conference. It was organized in November 2022 at Institute Mihajlo Pupin premises.

Figure 1. Second Ph.D. Workshop, University of Galway, May 2022

Figure 2. Third Ph.D. Workshop, Institute Mihajlo Pupin, November 2022

The research conducted in the SINERGY framework was presented at the SINERGY International Conference, please check D5.4.

Figure 3. SINERGY Conference, September 2023

# 3 Engagement of Early Stage Researchers from IMP

| Dea Pujić | |
|---|---|
| Engaged in SINERGY activities since | Year 2021 |
| Topics of research | • Renewable energy sources and data-driven services |
| Activity #1 | • Participation in the LAMBDA PhD workshop, June 2021 |
| Activity #2 | • Participation in the 1st SINERGY Workshop, November 2022 |
| Activity #3 | • Staff exchange activities, elaboration of pilots scenarios, implementation of innovative solutions |

**Publications**

- Dea Pujić and Valentina Janev (2021) Machine Learning Based Wind Turbine Production Forecaste, LAMBDA Ph.D. workshop, June 2021.

**Abstract:** Given the fact that renewable energy sources are increasing their share in the electricity market, in order to maintain the stable grid, i.e. match the production and the demand, it is crucial to have accurate prediction of the expected accessible energy. Therefore, this paper is focused on providing the model for wind turbine production short-term forecast. The model is deep neural network which includes LSTM, convolutional and dense layers, trained by the real world data obtained from the wind farm in Krnovo, Montenegro. The model was successful in a goal of providing competent prediction, so performances and results of the proposed model are given in this paper.

**Keywords:** renewable energy sources, Machine Learning, data-driven services.

- D. Pujić and N. Tomašević, "Hybrid ensemble neural network approach for photovoltaic production forecast," *2021 29th Telecommunications Forum (TELFOR)*, Belgrade, Serbia, 2021, pp. 1-4, doi: 10.1109/TELFOR52709.2021.9653369.

**Abstract:** With the main goal of saving the environment and reducing the amount of burnt fossil fuels, the penetration of renewable energy sources as a share of the electrical energy production is constantly increasing. However, this growth significantly jeopardizes electrical grid stability, since renewable sources highly depend on the meteorological conditions, which are stochastic by their nature. Therefore, careful planning of energy use is necessary, which is why a photovoltaic production forecaster model has been presented within this paper. The main focus was presenting a hybrid ensemble neural network approach which combines ensembling method with complex LSTM + CNN networks with the aim of improving forecasting performance. The approach has been tested using real-world year-long data from the town of Adeje in Tenerife and the results show an improvement in forecasting precision in comparison with the conventional ensemble model and with the hybrid approach on the test data, both state-of-the-art solutions.

**Keywords:** renewable energy sources, Machine Learning, data-driven services.

- Dea Pujić, Marko Jelić, Marko Batić, Nikola Tomašević, Application of Reinforcement Learning for Control of Heat Pump Systems. In: Zdravković, M., Trajanović, M., Konjović, Z. (Eds.) ICIST 2022 Proceedings, 71-74, 2022.

**Abstract:** With the proliferation of heat pump systems for both heating and cooling applications for a wide range of space volumes, from isolated rooms to whole houses and buildings, their efficient operation is paramount to facilitate the transition to a more efficient building stock and reduction of greenhouse gas emissions. Also, phasing out polluting non-renewable fossil fuel-based heating systems

in favor of heat pumps contributes notably to the electrification of the thermal domain and allows for a more notable share to be facilitated by clean and renewable generation in the future. Therefore, on top of modeling approaches for these types of systems, adequate control algorithms need to be developed and deployed to ensure the proper utilization of flexibility that these devices offer. This paper presents a set of techniques based on reinforcement learning for heat pump control of room temperature based on varying source and user loop flow rates as control inputs and discusses the implications of a selection of different control strategies on the observed indoor temperature variables.

**Keywords:** modeling of heat pump systems, reinforcement learning.

- Dea Pujic, Valentina Janev, Framework for optimizing neural network hyper parameters for accurate wind production forecasting. In: Zdravković, M., Trajanović, M., Konjović, Z. (Eds.) ICIST 2023 Proceedings, 2023.

**Abstract:** In order to decrease the amount of burnt fossil fuels, penetration of RES is constantly increasing on the energy production side. However, this is influencing destabilization of electrical grid, due to mismatch between the electrical production and the demand. Hence, accurate day-ahead forecast of the RES production is crucial for energy planning and dispatch. Since neural networks were proven to be one of the most precise modeling approaches for production forecast, this paper presents framework for optimizing neural network hyper parameters in order to reduce time required for model selection and select automatic and generic approach in the modeling approach.

**Keywords:** wind production forecaster, neural networks, artificial intelligence, grid stability.

- Valentina Janev, Maria-Esther Vidal, Dea Pujić, Dušan Popadić, Enrique Iglesias, Ahmad Sakor, Andrej Čampa: Responsible Knowledge Management in Energy Data Ecosystems. Energies 2022, 15(11), 3973
  **DOI:** https://doi.org/10.3390/en15113973

**Abstract:** This paper analyzes the challenges and requirements of establishing energy data ecosystems (EDEs) as data-driven infrastructures that overcome the limitations of currently fragmented energy applications. It proposes a new data- and knowledge-driven approach for management and processing. This approach aims to extend the analytics services portfolio of various energy stakeholders and achieve two-way flows of electricity and information for optimized generation, distribution, and electricity consumption. The approach is based on semantic technologies to create knowledge-based systems that will aid machines in integrating and processing resources contextually and intelligently. Thus, a paradigm shift in the energy data value chain is proposed towards transparency and the responsible management of data and knowledge exchanged by the various stakeholders of an energy data space. The approach can contribute to innovative energy management and the adoption of new business models in future energy data spaces.

**Keywords:** data integration systems; energy big data; knowledge graphs; data exchange; semantic interoperability; big data analytic

- Pujić, D.; Tomašević, N.; Batić, M. A Semi-Supervised Approach for Improving Generalization in Non-Intrusive Load Monitoring. *Sensors* **2023**, *23*, 1444. https://doi.org/10.3390/s23031444

**Abstract:** Non-intrusive load monitoring (NILM) considers different approaches for disaggregating energy consumption in residential, tertiary, and industrial buildings to enable smart grid services. The main feature of NILM is that it can break down the bulk electricity demand, as recorded by conventional smart meters, into the consumption of individual appliances without the need for additional meters or sensors. Furthermore, NILM can identify when an appliance is in use and estimate its real-time consumption based on its unique consumption patterns. However, NILM is based on machine learning methods and its performance is dependent on the quality of the training data for each appliance. Therefore, a common problem with NILM systems is that they may not generalize well to new environments where the appliances are unknown, which hinders their widespread adoption and more significant contributions to emerging smart grid services. The main goal of the presented research is to apply a domain adversarial neural network (DANN) approach to improve the

generalization of NILM systems. The proposed semi-supervised algorithm utilizes both labeled and unlabeled data and was tested on data from publicly available REDD and UK-DALE datasets. The results show a 3% improvement in generalization performance on highly uncorrelated data, indicating the potential for real-world applications.

**Keywords:** domain adversarial neural networks; generalization; non-intrusive load monitoring; semi-supervised learning.

| **Marko Jelić** | |
|---|---|
| **Engaged in SINERGY activities since** | **Year 2021** |
| **Topics of research** | • Sustainability, optimization, heat pump systems, energy system planning, energy system operation, smart homes, user benchmarking<br>• Energy Efficiency Benchmarking for Smart Homes<br>• Energy use optimization, energy prosumers operations<br>• Challenges in Smart Grids |
| **Activity #1** | • Participation in the LAMBDA Ph.D. workshop, June 2021 |
| **Activity #2** | • Participation in the 1st SINERGY Workshop, November 2022 |
| **Activity #3** | • Staff exchange activities, elaboration of pilots scenarios, implementation of innovative solutions |

**Publications**

- Marko Jelić, Dea Pujić and Marko Batić (2021) Energy Efficiency Benchmarking for Smart Homes, LAMBDA Ph.D. workshop, June 2021.

**Abstract:** Numerous strategies were developed over the years in order to encourage users to reduce energy consumption and bolster energy efficiency. However, with increasing levels of efficiency achieved by most household appliances and high-consumption devices, one of the most impactful approaches that remain as a means to further increase energy efficiency is attempting to encourage users to behave in an energy efficient manner. More precisely, positive behavior change can be motivated through the creation of unique social pressure and competition. Namely, the idea of the methodology presented in this paper is providing a fair, normalized, comparable ranking (benchmark) between different energy consumptions of different users. Therefore, the ranking is supposed to motivate them to either retain a leading position in the ranking or to attempt to improve their behaviour and advance within the ranking.

**Keywords:** energy consumption, energy efficiency, smart homes.

- Marko Jelić, Darko Šošić, Nikola Tomašević (2021) Effects of coordinated prosumer operation on power distribution systems, *29th Telecommunications Forum (TELFOR)*, Belgrade, Serbia, 2021, pp. 1-4, doi: 10.1109/TELFOR52709.2021.9653268.

**Abstract:** The proliferation of distributed renewable energy sources and energy storage systems has presented a number of challenges for contemporary power systems that were designed with different operating modes in mind to what users of the modern age require. Since many users generally strive towards cost minimization in their day-to-day operation of these novel assets, the grid may experience varying levels of equipment loading depending on the control strategies that the users employ. This

paper aims to explore the effects on the grid that coordinated operation of energy prosumers at various levels of prosumer penetration.

**Keywords:** energy use optimization, energy prosumers, energy hub, smart grid.

- Marko Jelic, Marko Batic, Demand-side optimization of hybrid energy systems with heat pumps. In: Zdravković, M., Trajanović, M., Konjović, Z. (Eds.) ICIST 2023 Proceedings, 2023.

**Abstract:** Ensuring sustainability and energy-efficient operation is of utmost importance in the current era as humanity strives to facilitate the transition to green energy. As our energy systems become increasingly complex, incorporating multiple energy carriers and power transformation devices, it is crucial to find innovative solutions to maximize their potential. Heat pumps have emerged as a key enabler of sustainable heating and cooling, while also offering demand-side flexibility. However, effectively harnessing this flexibility poses a significant challenge. This paper presents a comprehensive methodology for optimizing hybrid energy systems in the long term by leveraging various flexibilities. By integrating different energy sources such as renewable energy generation and heat pumps, the system's overall performance and efficiency can be significantly enhanced. The proposed optimization framework aims to determine the optimal operation strategy for hybrid energy systems, considering factors such as energy demand, weather conditions, and electricity prices. It considers the dynamic nature of energy supply and demand, utilizing advanced optimization algorithms and predictive modeling techniques. By intelligently managing the flexibilities inherent in hybrid energy systems, the proposed methodology seeks to minimize operational energy costs, reduce greenhouse gas emissions, and enhance overall system efficiency. The outcomes of this research will contribute to the development of sustainable energy systems that are adaptable, efficient, and capable of accommodating the fluctuating nature of renewable energy sources. The findings can inform policymakers, energy planners, and system operators in making informed decisions to facilitate the transition towards a greener and more sustainable future.

**Keywords:** Demand-side optimization, development of sustainable energy systems.

- Marko Jelić, Marko Batić, Nikola Tomašević: Demand-Side Flexibility Impact on Prosumer Energy System Planning. Energies 2021, 14(21), 7076.
  **DOI:** https://doi.org/10.3390/en14217076

**Abstract:** Apart from numerous technical challenges, the transition towards a carbon-neutral energy supply is greatly hindered by limited economic feasibility of renewable energy sources. This results in their slow and bounded penetration in both commercial and residential sectors that are responsible for over 40% of final energy consumption. This paper aims to demonstrate that combined application of sophisticated planning methodologies at building-level and presents incentive mechanisms for renewables that can result in prosumers, featuring hybrid renewable energy systems (HRES), with economic performance comparable to that of conventional energy systems. The presented research enhances existing planning methodologies by integrating appliance-level demand side management into the decision process and investigates its effect on the planning problem. Moreover, the proposed methodology features an innovative and holistic approach that simultaneously assess electrical and thermal domain in both an isolated and grid-connected context. The analyzed hybrid system consists of solar photovoltaic, wind turbine and battery with thermal supply featuring solar thermal collector and a ground-source heat pump. Overall optimization problem is modeled as a mixed-integer linear program, while ranking of all feasible alternatives is made by the multicriteria decision-making algorithm against several technological, economic, and environmental criteria. A real-life scenario of energy system retrofit for a building in the United Kingdom was employed to demonstrate overall cost savings of 12% in the present market and regulation context.

**Keywords:** hybrid renewable energy systems; energy hub; demand side management; optimization; multicriteria decision making; energy planning.

- Marko Jelić, Dea Pujić, Nikola Tomašević, Paulo Lissa, Dayanne Peretti Correa, Marcus Keane: Case study of Aran Islands: Optimal DR control of heat pumps and appliances. In H. Alhelou, A. Moreno-Muñoz, P. Siano (Eds.) Industrial Demand

Response: Methods, Best practices, Case Studies, and Applications), ISBN: 9781839535611, DOI: 10.1049/PBPO215E_ch16 **(IMP, NUIG).**

**Abstract:** Demand response has proven to be a crucial mechanism in the process of flexibility exploitation on the demand side. Throughout the years, it has evolved and expanded, reaching more and more previously untapped potential sources. In that process, residential users have provided a significant buffering capacity for balancing energy production and demand, but this came with a few challenges. With more and more households transitioning from being purely energy users to smart homes and energy prosumers with distributed renewable energy generation, new possibilities have opened up for integrated optimisation approaches that make the best use of both locally generated and grid-supplied energy as well as energy storage systems.

**Keywords:** Demand response, smart homes, energy prosumers, optimization.

| **Dušan Popadić** | |
|---|---|
| **Engaged in SINERGY activities since** | **Year 2021** |
| **Topics of research** | • Emergencies and Restoration of Power Grid<br>• Knowledge Graphs and Interoperability Standards for the Energy Domain |
| **Activity #1** | • Participation in the LAMBDA Ph.D. workshop, June 2021 |
| **Activity #2** | • Participation in the 1st SINERGY Workshop, November 2022 |
| **Activity #3** | • Participation in the 2nd SINERGY Workshop, May 2023 |
| **Activity #4** | • Research on application of semantic technologies for the energy domain |

**Publications**

- Coordination Platform for Handling Emergencies and Restoration of Power Grid, LAMBDA Ph.D. workshop, June 2021.

**Abstract:** Transmission service operators (TSOs), regional security centres (RSCs), distribution service operators (DSOs), generation units (GUs) and balancing service providers (BSPs) need quick and reliable way of communication in order to secure power grid balance. They need to exchange information about grid stability, problems on the grid and defense plans in an easy and traceable way. In this paper we present software solution for handling these situations efficiently.

**Keywords:** Power Grid stability, Emergencies, Restoration, software tools.

- Janev, V., Popadić, D., Pujić, D., Vidal, M., Endris, K. *Reuse of Semantic Models for Emerging Smart Grids Applications*. In: Zdravković, M., Trajanović, M., Konjović, Z. (Eds.) ICIST 2021 Proceedings, pp.119-123, 2021.

**Abstract:** Data in the energy domain grows at unprecedented rates. Despite the great potential that IoT platforms and other big data-driven technologies have brought in the energy sector, data exchange and data integration are still not wholly achieved. As a result, fragmented applications are developed against energy data silos, and data exchange is limited to few applications. Therefore, this paper identifies semantic models that can be reused for building interoperable energy management services and applications. The ambition is to innovate the Institute Mihajlo Pupin proprietary SCADA system and to enable integration of PUPIN services/applications in the European Union (EU) Energy Data Space. The selection of reusable models has been done based on a set of scenarios related to electricity balancing services, predictive maintenance services, and services for residential, commercial and industrial sector.

**Keywords:** Energy Data Spaces, Semantic models, Smart Energy Grids.

- Dušan Popadić, Enrique Iglesias, Ahmad Sakor, Valentina Janev, Maria-Esther Vidal: Towards a Solution for an Energy Knowledge Graph, ISIC 2022 (Best Paper Award), Springer Nature. ISBN 978-981-19-7125-9 https://link.springer.com/chapter/10.1007/978-981-19-7126-6_1

**Abstract:** The recently adopted EU strategy for energy system integration calls for a more integrated energy infrastructure based on innovative technologies. The modernization of the energy sector also aims to solve the problem of the current fragmented applications (built against energy data silos) and enable data sharing within energy communities by leveraging energy data spaces and semantic technologies as a crucial technology for interoperability. This paper addresses the challenges of energy data management and discusses the process of creating a knowledge graph, for example, energy data space, motivated by the needs of the stakeholders from Serbia and related to the integration of a large number of different renewable energy sources (RES) with the proprietary SCADA system of the Institute Mihajlo Pupin. The Energy Knowledge Graph (KG) has been built by reusing the energy-based semantic data model and the SDM-RDFizer, an open-source tool and interpreter of the W3C Recommendations Standard R2RML and its RDF Mapping Language (RML) extension. The Energy KG has been deployed on a Smart Grid Architecture Model (SGAM) – compliant platform hosted at the Institute Mihajlo Pupin.

**Keywords:** Energy; Knowledge Graph; Mapping rules; Application; Services.

| **Marija Popović** | |
|---|---|
| **Engaged in SINERGY activities since** | **Year 2021** |
| **Topics of research** | • Emergency and restoration processes in smart grids: detection of system split and blackout, frequency deviation<br>• Maintenance coordination and planning in power systems |
| **Activity #1** | • Involved in the promotion of SINERGY project as a part of the booth in CIGRE conference in Zlatibor, Serbia, 2023 |
| **Activity #2** | • Participation in the LAMBDA Ph.D. workshop, June 2021 |
| **Publications** | |

- Marija Popović and Nikola Tomašević (2021) A blockchain-based Platform for Keeping Logs of Citizens' Consent, LAMBDA Ph.D. workshop, June 2021.

**Abstract:** The development of ICTs (Information and Communication Technologies) and the usage of personal data for both research and commercial purposes over the last years have brought the question of the protection of personal data. The GDPR (General Data Protection Regulation) has defined the ways how personal data should be treated, but the application of these requirements still remains an open issue. This paper is dedicated to the research of the blockchain advantages when it comes to providing the transparency of the usage of personal data and provides proof of concept where it demonstrates the application of blockchain in working with users' consents. Hyperledger Fabric was chosen as the development platform which proves as a suitable choice when it comes to achieving transparency, immutability, and modularity.

**Keywords:** Hyperledger Fabric, blockchain, General Data Protection Regulation.

## Katarina Stanković

| | |
|---|---|
| **Engaged in SINERGY activities since** | **Year 2021** |
| **Topics of research** | • Multi-objective optimization techniques for decision support systems<br>• Application of AI in process optimization<br>• Causal discovery for time-series data<br>• Control and automation of HVAC systems with integrated renewable energy sources<br>• Thermal modelling of HVAC system components |
| **Activity #1** | • Participation in the 3rd Ph.D. workshop, November 2022 |
| **Activity #2** | • Participation in the LAMBDA Ph.D. workshop, June 2021 |

**Publications**

- Katarina Stanković, Marko Jelić and Marko Batić (2021) The Cloud-based Control Platform for Multi-source Renewable Energy System, LAMBDA Ph.D. workshop, June 2021.

**Abstract:** Intermittent renewable energy supply combined with electric and thermal energy storage technologies can cover the highest possible share of electricity, heating and cooling needs. However, their integration within the HVAC (Heating, Ventilation and Air-Conditioning) systems could result in far too complex installations, requiring intelligent energy management platforms for achieving their energy-efficient work. This paper introduces a cloud-based control platform, deployed to one such multi-source/sink renewable energy system, that performs all control and monitoring tasks through its hierarchically organized algorithm structure. This cascade control paradigm entails conventional control enrichment by more intelligent superior optimization, which evaluates not only the current energy demand and state of resources but also the inherent flexibility on the demand side and predictive aspects of the local energy production from renewables. On the other hand, the control system layered architecture relies on SCADA system solution, with proven modularity, flexibility and connectivity, making the system easily upgradeable and accessible by the end-users.

**Keywords:** HVAC (Heating, Ventilation and Air-Conditioning) systems, optimization, flexibility, SCADA control system.

- Andjela Marković, Marko Batić, Katarina Stanković, Hybrid Approach in Thermal Demand Forecasting of a Building. In: Zdravković, M., Trajanović, M., Konjović, Z. (Eds.) ICIST 2023 Proceedings, 2023. **(IMP)**

**Abstract:** The energy consumption contributes enormously to the greenhouse effect, environmental damage and pollution. Enegy efficient building can reduce dependency on non-renewable energy sources. In order to switch to renewable energy sources demand forecasters are required in order to switch to renewable energy sources as they are highly weather dependent. Therefore, the main objective of this paper is to investigate modelling demand forecasters in lack of implemented control strategy. The study was undertaken in case of specific building in Italy. The findings indicate that modelled demand-forecaster achieved considerable results.

**Keywords:** HVAC, thermal model, grey box, ML, demand forecaster, negative feedback.

| **Miloš Nenadović** | |
|---|---|
| **Engaged in SINERGY activities since** | **Year 2022** |
| **Topics of research** | • APIs and Knowledge Graphs for Efficient Data Access and Interoperability in the Energy Domain |
| **Activity #1** | • Participation in the International SINERGY Conference on Smart and Innovative eNERGY Management, 26-28 September 2023. |
| **Activity #2** | • Participation in the 3rd Ph.D. workshop, November 2022 |

**Publications**

- Miloš Nenadović (2023) Leveraging APIs and Knowledge Graphs for Efficient Data Access and Interoperability in the Energy Domain, International SINERGY Conference on Smart and Innovative eNERGY Management, 26-28 September 2023.

**Abstract:** Efficient data access and interoperability are critical factors in the energy domain with the orchestration of many different services requiring seamless communication. Streamlining data access and manipulation requires the presence of an interface that facilitates interaction between the various services on one side and energy-related data on the other. In this case, standardization is achieved by reusing standardized vocabularies, which are deployed in a centralized repository of knowledge. The creation of an ontology is the first of the two main aspects of this paper, involving use-case analysis, conceptualization, instantiation of the knowledge graph, and integration. The second aspect focuses on the design and implementation of an API serving as a bridge between services/users and the energy-domain ontology, highlighting its role in improving data interoperability and enabling efficient data retrieval. Real-world use cases demonstrate the benefits of the API and the ontology, showcasing enhanced integration, data sharing, and simplified data management processes. Furthermore, challenges and future developments are discussed, paving the way for future research in optimizing API functionality and extending support to additional services or data sources.

**Keywords:** Efficient data access, Interoperability, Ontology, API, Energy domain.

| Anđela Marković | |
|---|---|
| Engaged in SINERGY activities since | Year 2023 |
| Topics of research | • Advanced Hybrid Modeling in Building Thermal Demand Forecasting<br>• Strategic Development of Local Renewable Energy Communities<br>• Enhanced Controller Design: Merging MCDA and Machine Learning Techniques |
| Activity #1 | • Participation in the International SINERGY Conference on Smart and Innovative eNERGY Management, 26-28 September 2023. |
| Activity #2 | • Involvement in the Promotion of the Synergy Project at the 66th International Technical Fair, Belgrade, May 21-24, 2024. |

**Publications / Presentations**

- Anđela Marković, Marko Batić and Katarina Stanković (2023) Hybrid Approach in Thermal Demand Forecasting of a Building, ICIST 2023 – 13th International Conference on Information Society and Technology, Kopaonik, Serbia, March 12-15, 2023 (in publication)

- Anđela Marković, Valentina Janev, Nikola Tomašević and Marko Batić (2023) Approach to Energy System Modelling for Supporting Decarbonization Scenarios in Energy Communities, International SINERGY Conference on Smart and Innovative eNERGY Management, 26-28 September 2023.

**Abstract:** This research paper explores the approach to energy system modelling for supporting decarbonization scenarios in energy communities. Energy communities, comprising small-scale distributed energy systems, are increasingly being considered as a viable solution to achieve decarbonization goals. The paper discusses the steps involved in the energy system modelling process, including data collection, model development, and scenario analysis. The paper emphasizes the importance of energy system modelling in designing and implementing energy communities and highlights its potential to reduce carbon emissions, lower energy costs, and improve energy security. The paper concludes by emphasizing the critical role of energy communities in the transition towards a sustainable energy future.

**Keywords:** Energy system modelling, Decarbonization, Energy Communities, Renewable Energy, Energy Efficiency, PUPIN R&D Campus

| Igor Jovanović | |
|---|---|
| Engaged in SINERGY activities since | Year 2023 |
| Topics of research | • Multi-objective Energy Management System and Sizing Optimization with Load Shifting |

| Activity #1 | • Participation in the International SINERGY Conference on Smart and Innovative eNERGY Management, 26-28 September 2023. |
|---|---|

**Publications**

- Igor Jovanović, Marko Jelić, Nikola Tomašević (2023) Multi-objective Energy Management System and Sizing Optimization with Load Shifting, International SINERGY Conference on Smart and Innovative eNERGY Management, 26-28 September 2023.

**Abstract:** One of the steps towards the modern world of technology refers to the field of energy, especially when it comes to smart homes. With an increasing rate of digitalization, the need for efficient use of electricity as well as a controlled environmental impact is becoming greater. This leads to development of multi-criteria systems that takes into account several optimization types. Accordingly, a key problem to consider is implementing a model that receives the amount of energy produced data as an input, considering solar panels and wind turbines as energy sources, as well as the energy demand profile. Where the desired system outputs are the optimal energy dispatched to various energy assets with an assumed resolution of one hour, as well as determining the energy assets size. Consequently, two optimization aspects are of importance. The optimal amount of energy withdrawn from the grid, sold to the grid, stored in batteries or withdrawn from them is the first of two mentioned aspects. This optimization becomes multi-objective by considering the environmental impact through CO2 emissions. The second aspect is the sizing optimization, which refers to the optimal system configuration and design. Finally, demand-side management and the overall optimization process at the community level is analyzed in this paper. Moreover, the obtained results contribute to substantial electricity savings, which is directly correlated with financial aspects, as well as the recommendation to users towards the optimal use of appliances.

**Keywords:** Multi-objective optimization; Sizing optimization; Energy systems; Shifting loads; Smart homes; Photovoltaics; Wind power; Exact optimization methods; Approximate optimization methods; Demand-side management.

In the Institute Mihajlo Pupin, the following senior researchers were involved in SINERGY Activities:

- Dr. Valentina Janev, Project Coordination and Management;
- Dr. Nikola Tomašević, Project Coordination;
- Dr. Marko Batić, involved in piloting activities for the IMP Testbed;
- Dr. Lazar Berbakov, involved in piloting activities for the IMP Testbed;
- Dr. Valentina Timčenko, involved in staff exchange with AIT) and the organization of the SINERGY Conference;
- Dr. Slavica Bištjančič Rakas, involved in the organisation of the SINERGY Conference.

# 4 Engagement of Early Stage Researchers from AIT

| Anja Banjac | |
|---|---|
| Engaged in SINERGY activities since | Year 2021 |
| Topics of research | • Controller-Hardware-in-the-Loop for power electronics |
| Activity #1 | • Participation in training workshops |
| Activity #2 | • Training exercise development for IMP staff trainings (2022, 2023) |
| Activity #3 | • Dissemination activities (e.g. PCIM 2022, 2023) |
| Publications/ Presentations | |
| • A. Banjac, Z. Miletic, Simulation and modelling of Grid-connected converters SINERGY Training – Hands-on session (March 2022).<br>• A. Banjac, Z. Miletic, Grid Forming: Control Design, Validation Testing Results SINERGY Training – Hands-on session (December 2022). | |
| • Z. Miletic, W. Tremmel, A. Banjac, J. Stöckl and A. Tarraso, "Storage-less PV Grid Forming Inverter with Inertial reserve for the low inertia applications," 2023 25th European Conference on Power Electronics and Applications (EPE'23 ECCE Europe), Aalborg, Denmark, 2023, pp. P.1-P.8, doi: 10.23919/EPE23ECCEEurope58414.2023.10264551. | |

| Jovica Perevski | |
|---|---|
| Engaged in SINERGY activities since | Year 2023 |
| Topics of research | • Power system components, grounding and safety |
| Activity #1 | • Conference participation |
| Publications | |
| • Perevski, Jovica. / Identifikacija elektromehanskih nihanj v elektroenergetskih sistemih v realnem času z uporabo analize glavnih komponent: Real-time identification of power system oscillations using principal components analysis. 2022. | |
| **Abstract:** Stability problems are inherent to power systems due to their non-linear and dynamic nature. The stability challenges for small disturbances, which are the subject of this paper, are noticeable when one or more synchronous generators oscillate relative to each other. Poorly damped oscillations, without adequate countermeasures, can lead to instability of the system, which can lead to its collapse. Modal analysis proved to be a suitable approach for the study of poorly damped oscillations with simulations on computer models. A different approach is implemented in real-time, made possible by utilizing phasor measurements of electrical quantities. However, when operating a real system, even under the most optimistic conditions, we cannot expect as much insight into the | |

operating state of the system as it is possible with modal analysis on computer models. This paper describes a method that allows the connection between real-time measurements and the modal analysis results of a computer model using principal component analysis. The method is tested using the DigSILENT Power Factory software on a 39-node model. Based on the model, a database was compiled with the results of the modal analysis as well as with the timely fluctuations of the measured quantities. The data processing is performed in the Matlab software environment.

**Keywords:** small-signal stability, principal components analysis, spectral analysis, Power Factory, power system oscillations, modal analysis, mode shape.

| Thi Kim Bich Pham | |
|---|---|
| Engaged in SINERGY activities since | Year 2023 |
| Topics of research | • Local energy communities, energy markets |
| Activity #1 | • Sinergy workshop participation |
| Activity #2 | • Sinergy conference participation |

**Publications**

- Thi Kim Bich Pham, Bharath Varsh Rao and Wilhelm Süßenbacher Peer-to-peer Energy Market incentivizing Energy Efficiency for Local Energy Communities in Austria, Sinergy Conference 2023.

**Abstract:** Local communities are increasingly embracing peer-to-peer energy trading as a workable approach to facilitating direct energy trade, advancing renewable energy integration, and democratizing the energy market. An overview of previous studies' findings on performance enhancement, the impact on the physical energy network, and the development of energy-exchange systems has been made available. However, there is little discussion of pricing competence and energy efficiency in peer-to-peer trading in local energy communities, which this paper aims to do. The implementation requirements of Austrian rules for peer-to-peer energy accounting are especially examined in this article. It investigates the effects of adopting peer-to-peer trade in local communities on the grid parameters and offers analysis and insights into this effect. The need of efficient trading algorithms for maximizing the potential of peer-to-peer energy trading is also highlighted in the article.
Keywords:

**Keywords:** Local community, energy trading, blockchain, renewable energy, smart grid, distribution networks, simulation, grid analysis.

| Florian Strebl | |
|---|---|
| Engaged in SINERGY activities since | Year 2023 |
| Topics of research | • Deployment of energy communities |
| Activity #1 | • Sinergy conference participation |

| Publications |
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| • Florian Strebl and Bharath-Varsh Rao, Impact of large-scale Deployment of Energy Communities on Distribution Grids, Sinergy Conference 2023. |
| **Abstract:** The presented work shows a master thesis aimed to investigate the impact of a large-scale deployment of Renewable Energy Communities (REC) on low voltage (LV) as well as medium voltage (MV) distribution grids. A REC represents a citizen-driven, economic and legal entity, destined to enforce the further installation of renewable energy sources (RES) by, first of all, enhancing acceptance of the broader public. This shall be accomplished by letting citizens benefit from local RES production which then increases the attractiveness of local RES investments leading to further RES rollout, letting citizens benefit from it even more. While RECs have been legally introduced within the "Clean Energy for all Europeans" package back in 2019, large-scale real-world implementations are still the missing piece. In general, the intrinsic behaviour of RECs regarding optimal capacity management and integration of RES as well as market design have been well researched within the past years. Due to the mentioned lack of real-world implementations and therefore the negligible overall capacity of RECs, the impact of these communities on the outer LV/MV grid has not been well researched so far. The aim of this work is to address the gap between RECs and distribution grids. Questions to be researched are if there is a way to locally operate RECs in a matter so they support the outer LV/MV grid, at which point in time or installed REC capacity they have to be accounted for from a grid operation viewpoint and if there is a conflict of interest between local, economic optimization and overall grid stability and capacity management. Expected results are a certain REC capacity value in respect to the observed outer grid at which their behaviour has to be accounted for. Also, a sensitivity analysis regarding local optimization versus global grid operation parameters is wished. Finally, recommendations on REC design and control, so that it aids the grid, will be given. |
| **Keywords:** Energy Community, Power System Digitalisation, Smart Grid. |

| Nina Fuchs | |
|---|---|
| **Engaged in SINERGY activities since** | **Year 2021** |
| **Topics of research** | • DC grid planning and planning tool development |
| **Activity #1** | • Participation in Sinergy Ph.D. workshops |
| **Publications** | |
| • Jambrich, Gerhard ; Fuchs, Nina. / CIRED WG 2019-1 DC distribution networks - Final Report. in: DC DISTRIBUTION NETWORKS - WG 2019-1. 2021. | |
| • Fuchs, Nina; Jambrich, Gerhard ; Brunner, Helfried. / Simulation Tool for Techno-Economic Analysis of Hybrid ACDC Low-Voltage Distribution Grids. Proceedings of CIRED Online 2021. 2021. | |

| Troy Eskilson | |
|---|---|
| **Engaged in SINERGY activities since** | **Year 2022** |

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|---|---|
| Topics of research | • Energy efficiency of power electronics converters |
| Activity #1 | • Participation in Sinergy Ph.D. workshops |
| **Publications** | |
| • T. Eskilson and C. N. M. Ho, "Design of a Low-latency Power Electronics-based Power-HIL System for an EV Motor Controller," 2021 IEEE Energy Conversion Congress and Exposition (ECCE), Vancouver, BC, Canada, 2021, pp. 4719-4723, doi: 10.1109/ECCE47101.2021.9595928. | |

| **David Reihs** | |
|---|---|
| Engaged in SINERGY activities since | Year 2021 |
| Topics of research | • Energy communities, renewables and electric vehicle integration |
| Activity #1 | • Sinergy workshop participation |
| **Publications** | |
| • Reihs, D., Bouda, F., Leimgruber, F. M., Machtinger, K., Strasser, T. I., Stefan, M., Einfalt, A., & Schober, L. (2023). Unlocking customer flexibilities through standardized communication interfaces. e & i Elektrotechnik und Informationstechnik, 140(5), 441-451. https://doi.org/10.1007/s00502-023-01153-1 | |
| • Yu, Y., Reihs, D., Wagh, S., Shekhar, A., Stahleder, D., Mouli, G. R. C., Lehfuss, F., & Bauer, A. P. (2022). Data-Driven Study of Low Voltage Distribution Grid Behaviour With Increasing Electric Vehicle Penetration. IEEE Access, 6053-6070. https://doi.org/10.1109/ACCESS.2021.3140162 | |
| • Cejka, S., Reihs, D., Fina, B., Stefan, M., Hauer, D., & Zeilinger, F. (2022). Typical future energy communities -- an analysis on operational areas, member structure and used infrastructure. in CIRED Porto Workshop 2022: E-mobility and power distribution systems (S. 1-5) https://doi.org/10.1049/icp.2022.0757 | |
| • Stahleder, D., Übermasser, S., Reihs, D., Ledinger, S., & Lehfuss, F. (2021). Electric Vehicle Car Park Charging Simultaneity and Grid Connection Power Requirement Analysis. in CIRED 2021 Proceedings | |

| **Denis Vettoretti** | |
|---|---|
| Engaged in SINERGY activities since | Year 2021 |
| Topics of research | • Power system controls |

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|---|---|
| **Activity #1** | • Training support |
| **Activity #2** | • Workshop participation |
| **Publications** | |
| • Tayyebi Khameneh, A., Magdaleno, A., Vettoretti, D., Chen, M., Prieto-Araujo, E., Anta, A., & Dörfler, F. (2022). System-level performance and robustness of the grid-forming hybrid angle control. Electric Power Systems Research, (108503). https://doi.org/10.1016/j.epsr.2022.108503 | |
| • Korner, C., Vettoretti, D., Taljan, G., Auer, M., & Stern, P. (2021). Austrian pilot community in Gasen, Styria (ERA-NET Project CLUE). in Proceedings ComForEn 2021 (S. 77-85) | |
| • Lauss, G., & Vettoretti, D. (2021). Real-time simulation activities and real-time based HIL simulation methodologies. in Proceedings OPAL-RT´S 13TH CONFERENCE ON REAL-TIME SIMULATION | |

| **Eder Baron-Prada** | |
|---|---|
| **Engaged in SINERGY activities since** | **Year 2022** |
| **Topics of research** | • Power electronics converter controls for DC and hybrid ACDC grids |
| **Activity #1** | • Sinergy Workshop participation |
| **Publications** | |
| • Baron-Prada, E., Anta, A., Makoschitz, M., & Dörfler, F. (2023). H∞-Based Double Grid Forming Controller of Multi-Modular Converters in a Hybrid AC/DC Grid. in Proceedings https://doi.org/10.1109/compel52896.2023.10221196 | |
| • Mojica-Nava, E., Ruiz, F., & Baron-Prada, E. (2022). Fully Distributed Transactive Control Considering Pricing Dynamics and Network Constraints. IEEE Transactions on Smart Grid, 1566 - 1576. https://doi.org/10.1109/TSG.2022.3186163 | |

# 5 Engagement of Early Stage Researchers from NUIG

| Luis Miguel Blanes Restoy | |
|---|---|
| Engaged in SINERGY activities since | Year 2021 |
| Topics of research | • Ground Source Heat Pumps;<br>• Geothermal Heating;<br>• District Heating;<br>• Energy Efficiency in Buildings. |
| Activity #1 | • Planning and organisation of SINERGY events; |
| Activity #2 | • Participation in SINERGY conference (online); |
| Activity #3 | • Pilot development Alice Perry Geothermal Pilot; |
| Activity #4 | • Pilot development Aras de Brun Pilot; |
| Activity #5 | • Efficient Building Operation Lecture Series. |
| Publications | |
| • J. Stöckl et al., "Survey on Technologies Driving the Smart Energy Sector," 2021 29th Telecommunications Forum (TELFOR), Belgrade, Serbia, 2021, pp. 1-4, doi: 10.1109/TELFOR52709.2021.9653403. | |
| • Piccinini, A.; Blanes, L.M.; Seri, F.; D'Angelo, L.; Keane, M.M. ModSCO. Online Reduced Order Models (ROM) to Address the Performance Gap. Proceedings 2019, 20, 18. https://doi.org/10.3390/proceedings2019020018 | |

| Dayanne Peretti Correa | |
|---|---|
| Engaged in SINERGY activities since | Year 2022 |
| Topics of research | • Building Smart Readiness;<br>• Demand - Response;<br>• Building Energy Modelling (MATLAB);<br>• Smart Energy Communities (Islands). |
| Activity #1 | • Participation and organisation of SINERGY events; |
| Activity #2 | • Participation in Ph.D. Exchange Workshop (Galway) |
| Activity #3 | • Staff Exchange stay in Belgrade |

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|---|---|
| **Activity #4** | • Training session (Vienna) |
| **Activity #5** | • Participation in SINERGY Conference (Belgrade); |
| **Activity #6** | • Pilot development (Aran Islands - Galway); |
| **Publications** | |
| • Peretti Correa, Dayanne & Jelić, Marko & Pujić, Dea & Yousefi, Shima & Keane, Marcus & Tomasevic, Nikola. (2022). Autonomous Demand Response Control using Heat Pumps in Residential and Commercial Buildings. 1-4.https://ieeexplore.ieee.org/document/9983741<br>**Abstract:** The energy used for heating and cooling has a significant impact on the electricity bills of residential and commercial buildings, and heat pumps have been installed as a solution to reduce these costs. In Europe, around 11\% of the buildings already have heat pumps installed, but there is still a lack of optimization of their usage profile to maintain the thermal comfort of the buildings and the equipment efficiency. Moreover, buildings with photovoltaic (PV) energy generation have additional flexibility that can be explored, but the operational complexity also increases, which makes finding the optimal profile to enhance self-consumption challenging. Techniques for energy optimization and building modelling can help to identify the best energy profile in an automated way, facilitated by IoT devices and advanced communication infrastructure. The objective of this paper is to provide a framework to perform autonomous demand response control actions and demonstrate a use case for improving the usage of heat pumps. This includes the data to be collected for the simulation of thermal patterns and to create the optimal curve of energy usage in two real scenarios. The achievements of this study show that remote access to the system data can allow for enhanced energy usage, through the utilisation of building modelling and electric energy optimization models. | |
| • Marko Jelić, Dea Pujić, Nikola Tomašević, Paulo Lissa, Dayanne Peretti Correa, Marcus Keane. (2022). Case study of Aran Islands: optimal demand response control of heat pumps and appliances. Industrial Demand Response Methods, best practices, case studies, and applications. Edited by Hassan Haes Alhelou, Antonio Moreno-Muñoz and Pierluigi Siano. The Institution of Engineering and Technology 2022. ISBN: 9781839535611. Chapter DOI: 10.1049/PBPO215E_ch16 | |

| **Paulo Lissa** | |
|---|---|
| **Engaged in SINERGY activities since** | **Year 2023** |
| **Topics of research** | • Smart Grid;<br>• Artificial intelligence;<br>• Machine Learning;<br>• Deep Learning;<br>• Energy Management. |
| **Activity #1** | • Ph.D. and Staff Exchange visits (Galway) |
| **Publications** | |

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|---|
| • Paulo Lissa, Conor Deane, Michael Schukat, Federico Seri, Marcus Keane, Enda Barrett. Deep reinforcement learning for home energy management system control. Energy and AI, Volume 3, 2021, 100043, ISSN 2666-5468, https://doi.org/10.1016/j.egyai.2020.100043 |
| • Lissa, P., Schukat, M. & Barrett, E. Transfer Learning Applied to Reinforcement Learning-Based HVAC Control. SN COMPUT. SCI. 1, 127 (2020). https://doi.org/10.1007/s42979-020-00146-7 |

| Mariya Chukkiriyan Joy | |
|---|---|
| Engaged in SINERGY activities since | Year 2022 |
| Topics of research | • Energy Flexibility in Buildings. |
| Activity #1 | • Participation in SINERGY Conference (Belgrade) |
| Publications | |
| • Mariya Chukkiriyan Joy, Marcus Keane. Energy Flexibility Assessment for Buildings in Ireland. Book of Abstracts. International Conference on Smart and Innovative eNERGY management. 26 – 28 September 2023. Institute Mihajlo Pupin, Belgrade, Serbia. | |

| Raquel de Castro Rodrigues Lima | |
|---|---|
| Engaged in SINERGY activities since | Year 2022 |
| Topics of research | • Water/waste management;<br>• Global management systems;<br>• Sustainability in buildings;<br>• Economic evaluation. |
| Activity #1 | • Participation in Ph.D. Exchange workshops (Galway 2022) |
| Activity #2 | • Participation in Ph.D. Staff Exchange (Galway 2023) |
| Publications | |
| • Brychkov, D., Goggins, G., Doherty, E. et al. A systemic framework of energy efficiency in schools: experiences from six European countries. Energy Efficiency 16, 21 (2023). https://doi.org/10.1007/s12053-023-10099-4 | |

| Junlin Lu | |
|---|---|
| Engaged in SINERGY activities since | Year 2022 |
| Topics of research | • Reinforcement Learning;<br>• Deep Learning;<br>• Inverse Reinforcement Learning, Game Theory, Multi-objective Optimization and Smart Grid. |
| Activity #1 | • Participation in SINERGY Ph.D. workshop (Galway) |
| Publications | |
| • Lu, J., Mannion, P., Mason, K.: A Multi-objective multi-agent deep reinforcement learning approach to residential appliance scheduling. IET Smart Grid. 5(4), 260–280 (2022). https://doi.org/10.1049/stg2.12068 | |

| Mostafa Rezaeimozafar | |
|---|---|
| Engaged in SINERGY activities since | Year 2022 |
| Topics of research | • Power Systems Analysis;<br>• Renewable Energy Technologies;<br>• Distributed Generation;<br>• Microgrids Optimization;<br>• Smart Grid. Energy Storage. |
| Activity #1 | • Participation in SINERGY Ph.D. workshop (Galway) |
| Publications | |
| • Mostafa Rezaeimozafar, Rory F.D. Monaghan, Enda Barrett, Maeve Duffy. A review of behind-the-meter energy storage systems in smart grids. Renewable and Sustainable Energy Reviews. Volume 164, 2022, 112573, ISSN 1364-0321. https://doi.org/10.1016/j.rser.2022.112573. | |

| Shima Yousefigarjan | |
|---|---|
| Engaged in SINERGY activities since | Year 2022 |
| Topics of research | • Simulation data exchange;<br>• BIM<br>• Sustainable Construction<br>• Digital Twins |

| | |
|---|---|
| **Activity #1** | • Participation in SINERGY Ph.D. workshop (Galway) |
| **Publications** | |
| • Piccinini, A.; Seri, F.; D'Angelo, L.; Yousefigarjan, S.; Keane, M.M. ModSCO a Web Application Based on a Grey-Box Model to Support the Estimation of the Energy Savings in Building Retrofits. Environ. Sci. Proc. 2021, 11, 31. https://doi.org/10.3390/environsciproc2021011031 | |

| **Xue Yang** | |
|---|---|
| **Engaged in SINERGY activities since** | **Year 2022** |
| **Topics of research** | • Anomaly detection;<br>• Reinforcement learning. |
| **Activity #1** | • Participation in SINERGY Ph.D. workshop (Galway) |
| **Publications** | |
| • X. Yang, E. Howley and M. Schukat, "The Application of Reinforcement Learning to the FlipIt Security Game," 2022 Cyber Research Conference - Ireland (Cyber-RCI), Galway, Ireland, 2022, pp. 1-8, doi: 10.1109/Cyber-RCI55324.2022.10032686. | |

| **Tadgh Cummins** | |
|---|---|
| **Engaged in SINERGY activities since** | **Year 2022** |
| **Topics of research** | • Green hydrogen;<br>• Techno-economic analysis;<br>• Zero emissions public transport. |
| **Activity #1** | • Participation in SINERGY event "Smart Grid Technology underpinning Sustainable and Secure Energy in Europe" (Galway) |
| **Publications** | |
| • Tadgh Cummins and Rory Monaghan. 2023. An online tool for guiding bus fleet decarbonisation through green hydrogen and electrification. Poster presentation at the Hydrogen Ireland Conference 2023. | |

| Shimita Rudra (MSc) | |
|---|---|
| Engaged in SINERGY activities since | Year 2023 |
| Topics of research | • Natural Language Processing;<br>• Data analytics |
| Activity #1 | • Participation in Staff Exchange (Belgrade 2023) and proposal writing. |

| Gavin Larkin (MSc) | |
|---|---|
| Engaged in SINERGY activities since | Year 2023 |
| Topics of research | • Energy efficiency in buildings;<br>• Building simulation (IES); |
| Activity #1 | • Participation in SINERGY staff exchange event in Vienna (Smart Grid Mobilisation) |

| Matthew Broderick (MSc) | |
|---|---|
| Engaged in SINERGY activities since | Year 2023 |
| Topics of research | • Energy efficiency in buildings;<br>• Building simulation (IES);<br>• Thermal comfort in buildings |
| Activity #1 | • Participation in SINERGY staff exchange event in Vienna (Smart Grid Mobilisation) |

# 6 Conclusion

The document reports about the results of WP4 activities, T4.3 titled Engagement of IMP's early stage researchers that address the Objective 2 of the SINERGY Project **Reinforcement of scientific and technology excellence of the linked institutions in domain of Smart energy management.**

In the last three years, as a result of the collaborative efforts of SINERGY partners (Institute Mihajlo Pupin, Austrian Institute of Technology and University of Galway), many activities were organized that mobilized many early stage researchers and involved them in activities such as

- preparation of a vision of their Ph.D. research and career paths (see for instance the results of the Ph.D. Workshops in Galway[1] (May 2022) and Belgrade[2] (November 2022) facilitated by Dr. Kevin Byron;
- elaboration of scenarios and writing joint papers;
- presentation of the research at the final SINERGY Conference.

In this deliverable, we have included all young researchers who have been impacted by the SINERGY activities, while the list of publication that explicitly acknowledge SINERGY can be found on SINERGY web site, please check Publications | Project Sinergy (project-sinergy.org).

[1] 2nd PhD Workshop, Galway, Ireland, June 2022 | Project Sinergy (project-sinergy.org)
[2] SINERGY Ph.D. Workshop, November 2022 | Project Sinergy (project-sinergy.org)