Nordic Energy Informatics Academy Conference 2025

Technical Program

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Preface

The Nordic Energy Informatics Academy Conference 2025 (EIA Nordic 2025) brought together researchers, innovators, and professionals across Europe and beyond to explore how digitalization and informatics can accelerate the sustainable transformation of the energy sector. Held over three days, the conference served as a vibrant forum for knowledge exchange, collaboration, and innovation at the intersection of energy systems and digital technologies.

Thanks to the dedicated efforts of the organizing and technical program committees, a total of sixty-five (65) submissions were received for EIA Nordic 2025. Each submission was evaluated through a rigorous single-blind peer-review process, with three expert reviewers assigned to each paper. Reviews were based on relevance, scientific quality, originality, and clarity. According to the review policy, a manuscript was accepted only if it received at least two positive recommendations.

As a result, fifty-one (51) high-quality research papers were accepted and presented across eleven thematic sections, including 43 full papers and 8 short papers. The strong alignment of submissions with the conference's specific scope, as well as the high standard of contributions from experienced research groups and ongoing collaborations within the Nordic energy informatics community, contributed to this acceptance outcome. All accepted papers have been published in the Springer Lecture Notes in Computer Science (LNCS) series, ensuring global visibility and scientific impact.

The conference opened with keynote speeches that set the tone for deep discussion on emerging energy informatics challenges and opportunities. The technical program included insightful presentations organized around the following focused themes:

- Energy Forecasting and Intelligent Control Systems
- District Heating, Thermal Systems, and Retrofit Strategies
- Building Simulation, Urban Energy, and Environmental Sensing
- Industrial Process Efficiency and Biomass Utilization
- Energy Informatics for Electric Vehicles and Mobility Systems
- Multi-Agent Systems and Local Market Coordination
- Policy, Metrics, and Infrastructure Performance
- Smart Building Systems and Semantic Data Integration
- Prosumer Optimization and Energy Storage in Local Energy Communities
- Grid-Oriented AI, Simulation, and Resilience
- Non-Intrusive Load Monitoring and Data Competitions

Each session provided a platform to present cutting-edge methods, innovative applications, and empirical case studies that address real-world energy challenges—from grid flexibility and urban energy sensing to semantic data modeling, battery storage, and AI-based resilience strategies.

In addition to the paper sessions, the conference featured a technical site visit to the KTH Live-in Lab, offering participants further opportunities to network and experience real-world energy innovation in action.

EIA Nordic 2025 has once again demonstrated the value of interdisciplinary research and the power of digital tools to drive impactful solutions in energy systems. The conference fostered new ideas, strengthened collaborations, and inspired the community toward the continued advancement of energy informatics.

July 2025
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Program

Program Overview

Date	Activity	Start time	End time
20-22 August	Registration	8:30	15:00
20 August	Opening Session	09:00	09:30
	Three Keynote Speeches	09:30	11:00
	Morning Coffee Break	11:00	11:15
	Paper Section: Energy Forecasting and Intelligent Control Systems	11:15	12:35
	Lunch Break	12:35	13:35
	Paper Section: District Heating, Thermal Systems, and Retrofit Strategies	13:35	15:15
	Afternoon Coffee Break	15:15	15:30
	Paper Section: Building Simulation, Urban Energy, and Environmental Sensing	15:30	17:10
21 August	One Keynote Speech	09:00	09:30
	Paper Section: Industrial Process Efficiency and Biomass Utilization	09:30	10:30
	Morning Coffee Break	10:30	10:45
	Paper Section: Energy Informatics for Electric Vehicles and Mobility Systems	10:45	12:25
	Lunch Break	12:25	13:25
	Paper Section: Multi-Agent Systems and Local Market Coordination	13:25	14:45
	Afternoon Coffee Break	14:45	15:00
	Paper Section: Policy, Metrics, and Infrastructure Performance	15:00	17:00
	Gala dinner	18:30	21:00
22 August	Paper Section: Smart Building Systems and Semantic Data Integration	09:00	10:40
	Morning Coffee Break	10:40	11:00
	Paper Section: Prosumer Optimization and Energy Storage in Local Energy Communities	11:00	12:20
	Lunch Break	12:20	13:20
	Paper Section: Grid-Oriented AI, Simulation, and Resilience	13:20	15:00
	Afternoon Coffee Break	15:00	15:20
	Paper Section: Non-Intrusive Load Monitoring and Data Competitions	15:20	16:00
	Closing Session and next year conference announcement	16:00	16:30
	Site visit	16:30	17:30

Program Day One (20th August 2025)

Activity	Start time	End time
Opening Session	09:00	09:30
Keynote Speeches • Overcoming barriers to unlock potential data exchange from building to energy domain by Arianna Fonsati (KTH Royal Institute of Technology, Sweden) • Reducing the energy performance gap by verifying functions and energy use in apartment buildings by Per Kempe (RISE Research Institutes of Sweden, Sweden) • Integrating Electric Mobility and Smart Buildings: Educational Perspectives on Sustainable Urban Development by Chiara Bordin (The Arctic University of Norway, Tromsø, Norway)	09:30	11:00
Morning Coffee Break	11:00	11:15
Paper Section: Energy Forecasting and Intelligent Control Systems ID 029 A Multi-Stage Deep Learning Framework for Short-Term Electricity Load Forecasting ID 052 Solaris AI: Enhancing Solar Energy Forecasting with Generative AI and Deep Learning ID 048 A Tool for Synthesizing and Implementing Medium Voltage Load Profiles ID 050 Decentralized Reinforcement Learning for Adaptive Power Sharing in Hybrid DC Microgrids	11:15	12:35
Lunch Break	12:35	13:35
Paper Section: District Heating, Thermal Systems, and Retrofit Strategies ID 033 Digitalization in District Heating: Comparative Insights from Denmark and Sweden on Adoption, Barriers, and Value Creation ID 055 Evaluating Retrofit Strategies and Decentralized Systems for the transition to Low-Temperature District Heating: A Simulation-Based Case Study in Borlänge, Sweden ID 051 Parametric study model for observing exergy balance through the series of subsystems in district heating ID 035 Demand-side Frequency Response based on District Heating System Integrated with Heat Pump ID 044 A parametric optimization approach for enviro-economic evaluation of energy renovation strategies – a case study on a congregation house in southern Sweden	13:35	15:15
Afternoon Coffee Break	15:15	15:30
Paper Section: Building Simulation, Urban Energy, and Environmental Sensing ID 057 Development of an Automated 3D Building Modeling Method and Urban-Scale Analysis of Heating and Cooling Loads ID 038 Research on 3D Modeling for Thermal Environment Simulation Using Publicly Available Map Data ID 045 Rooftop Irregularity Segmentation in Aerial Imagery Using Deep Learning ID 008 Autonomous Air Quality Monitoring System with Photovoltaic Energy Harvesting: A Sustainable Approach for Public Policies ID 030 How clean is the air you breathe during urban walk? A case study of Central London	15:30	17:10

Program Day Two (21st August 2025)

Activity		Start time	End time
Keynote Speech			
• Neighbors with Benefits: Modelling the Multi-Criteria Challenges of Peer Energy by Rúnar Unnþórsson (University of Iceland, Iceland)		09:00	09:30
Paper Section: Industrial Process Efficiency and Biomass Utilization			
ID 028	Examining the role of Digital Technologies and Artificial Intelligence in Climate Resilience and Energy Adaptation within Energy-Intensive Industries	09:30	10:30
ID 019	Energy Efficiency Optimization in Plastic Pyrolysis: A Data-Driven Modeling Study		
ID 027	Globally Optimal Scheduling for Industrial Energy Cost Reduction Under Dynamic		
Morning Coffee Break		10:30	10:45
Paper Section: Energy Informatics for Electric Vehicles and Mobility Systems			
ID 010	The Irish Highway Network: A Novel Test Instance for the Charging Station Location Problem	10:45	12:25
ID 032	Enhancing EVRP Benchmark Instances with Energy Estimates		
ID 018	Economic and Environmental Benefits of Centralized MILP Optimization of EV Fleet Charging		
ID 013	Electric Vehicle based virtual electricity network (EVEN) solution for performance enhancement in distribution networks		
ID 015	Variational Quantum Eigensolver-Based CaaS Business Model for V2G		
Lunch Break		12:25	13:25
Paper Section: Multi-Agent Systems and Local Market Coordination			
ID 021	Towards ICT-Enabled Multi-Agent based Operations in Local Energy Communities: A Proof of Concept	13:25	14:45
ID 024	A Peer-to-Peer Energy Management Model		
ID 026	Agent-based Flexibility Aggregation for a Distributed Redispatch		
ID 064	A Visualization Framework for Exploring Multi-Agent-Based Simulations: Case Study of an Electric Vehicle Home Charging Ecosystem		
Afternoon Coffee Break		14:45	15:00
Paper Section: Policy, Metrics, and Infrastructure Performance			
ID 020	Proper definitions of micro grid metrics are needed! – a generalizable framework	15:00	17:00
ID 065	Solar-Geothermal Power “HGS-ORC” System for Energy Co-generation: Energy, Economic and Environmental analysis		
ID 016	Towards the Integration of Data Space Technology in Hydrogen Research Workflows		
ID 054	Comparison of Outages Trends and Statistics in Nordic Countries Across Distribution Networks and their Impacts		

ID 025	Managing Risk in Distribution Systems with Solar Generation: A Case Study Using the MATPOWER Optimal Scheduling Tool		
ID 039	Smart Energy Management System With Individual Load Monitoring		
Gala dinner		18:30	21:00

Program Day Three (22nd August 2025)

Activity		Start time	End time
Paper Section: Smart Building Systems and Semantic Data Integration			
ID 041	Towards a Taxonomy for Application of Machine Learning and Artificial Intelligence in Building and District Energy Management Systems		
ID 046	Smart Building-Grid Interaction: A Taxonomy of Key Performance Indicators and Enabling Technologies		
ID 049	Dynamic Semantic Data Modeling of Space for Changes in HVAC Zones		
ID 014	Leveraging Generative AI and semantic data for improved operation of a real-life building	09:00	10:40
ID 012	Data-Driven Optimal Air-Balancing Control for Multizone Ventilation Systems with Design-to-Operation Adaptation		
ID 047	Development of an LSTM-Based Model for High-Resolution Downsampling and Reconstruction of HVAC Chiller Flow Data		
ID 036	Co-development by Academia and Industry: A Resource Management Tool for economic and ecological sustainability in buildings		
Morning Coffee Break		10:40	11:00
Paper Section: Prosumer Optimization and Energy Storage in Local Energy Communities			
ID 022	Evaluating the Potential for Developing Local Energy Communities in Sweden: Case Studies at Jättesten and Chalmers Campus		
ID 031	Data-driven Correlated Uncertainty Sets for PV Generation and Electricity Demand	11:00	12:20
ID 034	Battery Energy Storage Integration for BIPV Systems: A Multi-Scenario Economic Analysis and Optimization		
ID 062	Scheduling Heat Pumps for Balancing Thermal Storage and Grid Export		
Lunch Break		12:20	13:20
Paper Section: Grid-Oriented AI, Simulation, and Resilience			
ID 040	Green Hydrogen under Uncertainty: Evaluating Power-to-X Strategies Using Agent-Based Simulation and Multi-Criteria Decision Framework	13:20	15:00
ID 060	Synthesizing Fault Localization Datasets		
ID 042	Machine Learning-Based Cyberattack Detection in Power Data		

ID 056 Optimization of Second-Life Battery Energy Storage System in Buildings With Photovoltaic Panels: A Norwegian Case Study		
Afternoon Coffee Break	15:00	15:20
Paper Section: Non-Intrusive Load Monitoring and Data Competitions		
ID 006 ADRENALIN: Energy Data Preparation and Validation for HVAC Load Disaggregation in Commercial Buildings		
ID 002 Comparison of Three Algorithms for Low-Frequency Temperature-Dependent Load Disaggregation in Buildings Without Submetering		
ID 005 Advancing Non-Intrusive Load Monitoring: Insights from the Winning Algorithms in the ADRENALIN 2024 Load Disaggregation Competition	15:20	16:00
ID 003 Lessons Learned from the ADRENALIN Load Disaggregation Challenge		
ID 004 Business Model Innovation in Data Competitions: Insights from the 2024 ADRENALIN Load Disaggregation Challenge		
Closing Session and next year conference announcement	16:00	16:30
Site visit	16:30	17:30

Paper Abstracts

Energy Forecasting and Intelligent Control Systems

A Multi-Stage Deep Learning Framework for Short-Term Electricity Load Forecasting

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Abstract. Electricity load forecasting is essential for economic viability and reliable operations in modern, complex power systems. Although traditional statistical methods and deep learning methods can be utilized for predictions, they tend to fall short in capturing complex non-linear behaviors with increasing demand. For this reason, in this study, a new cascaded method, Multi-Stage Deep Learning Framework (MSDL) is proposed which can capture these behaviors more accurately. MSDL consists of three different architectures, namely Seasonal Decomposition (SD), Empirical Mode Decomposition (EMD), and Long Short-Term Memory (LSTM). In MSDL, the time series data is first decomposed into trend, seasonal, and residual components using SD. The residual component is then further decomposed into Intrinsic Mode Functions (IMFs) using EMD to extract intricate, high-frequency patterns. These components are subsequently used as inputs to LSTM models for forecasting. Benchmarking results demonstrate that the proposed method outperforms several reference models in terms of RMSE, MAE, and MAPE. The study also goes beyond performance comparison by investigating the influence of the quantity of IMFs on forecast accuracy. It has been shown that for the selected case study, including more than five IMFs in forecasting does not significantly increase prediction performance.

Keywords: Electricity Load Forecasting · Cascaded Models · Seasonal Decomposition · Empirical Mode Decomposition (EMD) · Long Short-Term Memory (LSTM)

Solaris AI: Enhancing Solar Energy Forecasting with Generative AI and Deep Learning

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Abstract. The growing adoption of solar energy presents both an opportunity and a challenge while clean and sustainable, solar power generation is highly variable due to weather conditions, making reliable forecasting critical for grid integration, planning, solar placement and energy stability. Solaris AI aims to address these challenges by integrating Generative AI with traditional Deep Learning models, creating an intelligent, explainable, and multilingual expert system for solar energy analysis. At its core, Solaris AI features an Artificial Neural Network (ANN) model trained on key meteorological parameters such as cloud cover, humidity, temperature, and wind speed to predict solar power output. To make these insights accessible to a wider audience, Solaris AI leverages Retrieval-Augmented Generation (RAG) techniques using OpenAI's language models and LangChain. This enables stakeholders, including government planners, policymakers, businesses, grid operators, and citizens to interact with the system in natural language, retrieve data, and even receive real-time model predictions. A clean, functional web interface paired with cloud deployment ensures scalability and usability. This hybrid system bridges the gap between data-driven forecasting and practical decision-making, supporting better integration and adoption of solar energy worldwide.

Keywords: Solar forecasting · Deep Learning· ANN· Generative AI· RAG, Explainable AI· Clean energy· Expert system· OpenAI

A Tool for Synthesizing and Implementing Medium Voltage Load Profiles

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Abstract. To support energy planning and grid investigations, this paper presents an open source tool to generate and integrate realistic synthetic load profiles (SLPs) into power system software. The tool assigns daily SLPs to all loads within a network and is compatible with Vision Network Analysis and OpenDSS. It features a Graphical User Interface (GUI) and employs the probabilistic Multivariate Elliptical Copula (MEC) method, using active power consumption data as input. Additional functionalities include preprocessing, clustering, and validation. Preprocessing handles outlier and duplicate removal via the interquartile range (IQR) and imputes missing values using linear interpolation or k-Nearest Neighbors (kNN). Clustering groups data by month and day type, and later by K-Means to identify different consumer types. A selected cluster serves as input to the MEC model, which can be conditioned on annual consumption, mean load, and peak load. Validation metrics include Mean Absolute Percentage Error (MAPE), Root Mean Square Error (RMSE), and Jensen-Shannon Divergence (JS-D). In a case study using real medium voltage (MV) load data from a Dutch city, the tool achieved an average MAPE of 0.56% for industrial and 0.51% for aggregated residential consumers. It also successfully assigned SLPs, performed load flow calculations, and extracted congestion-related results in both software environments.

Keywords: Load profile · Synthetic data generation · Power system software · Congestion · Preprocessing.

Decentralized Reinforcement Learning for Adaptive Power Sharing in Hybrid DC Microgrids

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Abstract. This paper presents a decentralized voltage control strategy for islanded DC microgrids using reinforcement learning (RL) to supplant conventional droop methods. A deep deterministic policy gradient (DDPG) agent is trained to generate real-time voltage references using only local measurements. This fully autonomous framework adapts to load dynamics and impedance mismatches without inter-unit communication. Simulation results show significant improvements in current sharing accuracy, transient suppression, and voltage regulation, establishing RL as a scalable control solution for next-generation micro-grids.

Keywords: Reinforcement learning · data-driven control · energy management · decentralized control · DC microgrids· hybrid distributed generation.

District Heating, Thermal Systems, and Retrofit Strategies

Digitalization in District Heating: Comparative Insights from Denmark and Sweden on Adoption, Barriers, and Value Creation

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Abstract. Digitalization holds significant potential to improve the efficiency, flexibility, and sustainability of District Heating (DH) systems. However, the transition toward digitalized DH is often constrained by challenges beyond technology—such as regulatory uncertainty, unclear business models, fragmented organizational capacity, and misaligned stakeholder incentives. This paper offers a comparative, qualitative analysis of how digitalization is adopted, perceived, and implemented in DH systems in Denmark and Sweden - two of the most mature DH markets globally. Based on expert survey data collected under the IEA DHC Annex TS9 initiative, the study explores adoption trends across operational, customer-facing, and strategic domains. Findings reveal that while digital tools like smart meters, SCADA systems, and AI-based analytics are being introduced, systemic barriers, such as GDPR-related constraints, lack of clear return on investment, and digital skills gaps, continue to slow progress. Denmark's strengths in infrastructure and coordination contrast with Sweden's more diverse but fragmented innovation landscape. The study identifies key enablers: tariff reform, regulatory sandboxes, and capacity building, and offers context-sensitive policy and strategic recommendations. These insights contribute to advancing digitalization in the DH sector and to shaping future research and policymaking in smart energy system transformation.

Keywords: Digitalization; District heating; Denmark; Sweden; Smart energy systems; Energy policy; Barriers; Business model innovation

Evaluating Retrofit Strategies and Decentralized Systems for the transition to Low-Temperature District Heating: A Simulation-Based Case Study in Borlänge, Sweden

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Abstract. Transitioning to low-temperature district heating (LTDH) is an imperative approach for decarbonizing energy supply systems in the Nordic region. This study introduces a novel evaluation of scalable renovation strategies and explores the integration of renewable technologies in a real Swedish residential area. Through aggregated urban building energy modeling and statistical historic level inputs, two sets of energy efficiency retrofit scenarios together with the projected climate conditions for 2020, 2050, and 2080 are systematically analyzed to determine their impact on energy demand, peak loads, emissions, and system optimization. Both operational and embodied carbon emissions are quantified, and the techno-economic feasibility of ground source heat pumps and photovoltaic-thermal (PVT) systems is assessed. The results indicate that deep retrofit measures can achieve up to a 35% reduction in peak loads, alongside significant improvements in energy efficiency and solar energy utilization. These findings highlight the value of coupling demand-side renovations with decentralized renewable generation to facilitate the transition towards LTDH implementation and enhance urban climate resilience. This research supports district-level renovation strategies, aligning with Sweden's pathway toward net-zero emissions.

Keywords: Low-Temperature District Heating (LTDH), Building Stock Renovation, Peak Load Reduction, Decentralized Energy Systems, Operational and Embodied Carbon Emissions, Urban Energy Simulation.

Parametric study model for observing exergy balance through the series of subsystems in district heating

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Abstract. District heating (DH) systems have evolved from steam-based heat transport using boilers to combined heat and power (CHP) generation, and more recently to low-temperature heat supply using heat pumps (HP). As DH systems represent a critical energy infrastructure in Nordic regions, it is essential to examine their performance in the context of urban energy transitions. This study investigates exergy consumption in representative archetypes of DH system by developing a parametric model that quantifies the exergy balance across three subsystems: heat generation, heat transfer, and heat exchange within buildings. The results of the parametric analysis indicate that exergy consumption associated with pumping is a more significant contributor to overall exergy balance than the exergy loss through heat dissipation. Specifically, the analysis reveals that the exergy input required for pumps consistently exceeds that required for heat generation. The key finding is that the heat transfer process, particularly the pumping operation, constitutes the primary source of exergy loss in DH systems, underscoring the importance of optimizing this component to enhance overall system efficiency.

Keywords: district heating, exergy consumption, exergy balance equation

Demand-side Frequency Response based on District Heating System Integrated with Heat Pump

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Abstract. The increasing penetration level of renewable generation in power systems leads to challenges in frequency stability due to system inertia reduction. This study investigates the potential of the district heating system (DHS) integrated with the variable-speed heat pump to provide demand-side frequency response services while meeting end-user heating demands. Dynamic models are developed considering the thermal inertia of the DHS with the heat pump, and the dynamic performance is analyzed under rotational speed disturbances. The demand-side frequency control is proposed which regulates the supply water temperature setpoint to adjust heat pump power consumption during primary and secondary frequency response processes. The effectiveness of the proposed control is validated through a town-level case study. Results show that the proposed control effectively reduces the frequency nadir and accelerates frequency recovery, particularly under large load disturbances. For a step load increase of 0.25 p.u., the frequency nadir improves from −0.0265 p.u. to −0.0241 p.u and the frequency settling time decreases from 973.2 s to 913.7 s. Additionally, the room temperature variation is less than 0.8 ℃ taking 2000 s, satisfying the acceptable thermal comfort criteria.

Keywords: District heating system, heat pump, Frequency response.

A parametric optimization approach for enviro-economic evaluation of energy renovation strategies – a case study on a congregation house in southern Sweden

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Abstract. This study explores sustainable energy renovation strategies for a congregation building in southern Sweden using a parametric optimization approach to balance passive and active measures. Passive measures include envelope and window improvements, and leakage control, while active measures involve photovoltaic integration and ventilation enhancements. The renovation aims to optimize energy use, thermal comfort, indoor air quality (IAQ), life cycle cost (LCC), and life cycle assessment (LCA). However, individual measures often conflict with other objectives. By integrating the optimization tool Opossum with ClimateStudio, which simulates energy, thermal, and PV performance, along with programmed LCC and LCA calculations, the study identifies optimal solutions. Results indicate a 24% energy reduction, 23% lower LCC, and 47% less CO_2 emissions without changing the ventilation system, though IAQ and comfort remain inadequate. With new ventilation, energy use increases, LCC rises by 53%, but CO_2 emissions reduce by 11%, resolving IAQ issues and improving comfort by 74%.

Keywords: Energy renovation, Parametric optimization, Life cycle costing, Photovoltaic systems, Life cycle assessment

Building Simulation, Urban Energy, and Environmental Sensing

Development of an Automated 3D Building Modeling Method and Urban-Scale Analysis of Heating and Cooling Loads

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Abstract. To achieve carbon neutrality (CN) by 2050, it is essential to develop systems that enable detailed and spatially explicit regional analyses, allowing for an accurate understanding of current urban energy consumption. In this study, we constructed a wide-area building database utilizing geospatial information and developed a system that visualizes and leverages this data through a WebGIS platform. This paper proposes a method for the automatic generation of 3D building models, based on GIS data, that are compatible with air-conditioning load calculations, and applies this approach to urban-scale energy analysis. For the building types of office, accommodation, dedicated store, and detached house, we defined the conditions necessary for the automatic generation of EnergyPlus-compatible 3D models and determined their geometry based on the arrangement of surrounding buildings. By analyzing the heating and cooling loads of each building using the generated 3D models and visualizing the results on a map, our findings suggest that combining a single office building with multiple detached houses may contribute to the leveling of heating and cooling demand.

Keywords: Geographic Information System (GIS), Energy Consumption, Simulation, Automation Modeling, Air Conditioning Load, Carbon Neutral.

Research on 3D Modeling for Thermal Environment Simulation Using Publicly Available Map Data

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Abstract. In Japan, the pursuit of carbon neutrality (CN) necessitates a substantial reduction in building energy consumption alongside the proactive integration of renewable energy sources. This study evaluates the effectiveness of a 3D modeling approach in estimating energy demand across multiple buildings.A 3D building model was developed using GIS data, site surveys, and open datasets to extract critical parameters, such as window-to-wall ratio (WWR). Subsequently, indoor environmental conditions, HVAC system specifications, and other relevant factors were incorporated to simulate energy consumption under various conditions. Despite employing a consistent methodology, the accuracy of simulations varied among buildings. Further analysis identified key determinants of accuracy, including the precision of 3D modeling, the functional use of buildings, and the definition of envelope performance parameters. These findings underscore the importance of high-quality data acquisition and parameter calibration in energy simulations. The insights gained contribute to the advancement of simulation methodologies, ultimately supporting more effective energy management and sustainable urban planning.

Keywords: Energy Simulation, PLATEAU, CASBEE.

Rooftop Irregularity Segmentation in Aerial Imagery Using Deep Learning

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Abstract. To achieve carbon neutrality (CN) by 2050, efforts have primarily focused on CN at the level of individual buildings. However, it is essential to consider how CN can be achieved for entire cities, including these buildings. This study aims to estimate the available space for solar panel installation on buildings in urban areas to enhance the utilization of photovoltaic systems. In this study, we propose a semantic segmentation method for estimating building shape (protruding parts and depressed parts relative to the reference plane), which significantly influences the available space for solar panel installation. We conducted semantic segmentation under five different conditions, varying the training and testing datasets to analyze the impact of roads in aerial imagery. Furthermore, to improve the extraction accuracy of protruding parts, this study proposes a weighted overlay method, which overlays five different inference images using various weight combinations. For protruding part extraction using the semantic segmentation method, an F-Score of 0.305 was achieved when roads were fully retained during training and inference, whereas an F-Score of 0.414 was obtained when roads were entirely removed during training and inference. However, the extraction of depressed parts was not successful. Additionally, the weighted overlay method improved the F-Score, achieving a maximum value of 0.725.

Keywords: Rooftop, Deep Learning, Semantic Segmentation

Autonomous Air Quality Monitoring System with Photovoltaic Energy Harvesting: A Sustainable Approach for Public Policies

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Abstract. Air quality measurement is essential for decision-making and the establishment of public policies that promote health, well-being, and sustainability. This work proposes an autonomous air quality monitoring system powered by photovoltaic energy, aiming to contribute to the expansion of sustainable environmental monitoring networks. The developed system incorporates energy harvesting elements, using solar panels and power management integrated circuits (PMICs) to ensure energy autonomy and portability. A prototype was built to monitor carbon monoxide (CO) and transmit measured data through Wi-Fi. This prototype kept continuous operation for four days having only solar power and batteries as energy sources. These results highlight the feasibility of using photovoltaic energy in low-power systems, especially in remote or hard-to-access locations, reinforcing the importance of sustainable technologies for air quality monitoring. A methodology to design air quality measurement projects was also developed, enabling the replication of the system in different contexts.

Keywords: Air quality, energy harvesting, photovoltaic energy, autonomous monitoring, PMIC.

How clean is the air you breathe during urban walk? A case study of Central London

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Abstract This paper presents a case study on air quality in Central London with focus on particulate matter (PM10 and PM2.5). The relationship between road width, traffic patterns, and particulate matter (PM10 and PM2.5) concentrations is explored in this study via a walking journey. GPS geographical analysis and portable air quality sensors are used to assess the air quality. The key results indicate that that narrower roads with high buildings in general exhibit irregular PM spikes which could be explained by trapped emissions and busy traffic. Larger roads (≥20m in width) have presented a more stable air quality which can be explained by an improved air circulation and consistent traffic flow. The results highlight the necessity for enhanced measures with specialized interventions such as the plantation of green walls and trees (green infrastructure) combined with improved traffic control. The results indicate the importance of traffic management and the importance of policies and strategies such as London's Urban Greening Factor (UGF), London Low Emission Zone (LEZ), Ultra Low Emission Zone (ULEZ), Congestion Charge Zone, and the support of electric transportation.

Keywords: air quality, green infrastructure, artificial intelligence, electric mobility, smart cities.

Industrial Process Efficiency and Biomass Utilization

Examining the role of Digital Technologies and Artificial Intelligence in Climate Resilience and Energy Adaptation within Energy-Intensive Industries

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Abstract. This study explores how digital technologies and Artificial Intelligence (AI) contribute to climate resilience and energy adaptation in energy-intensive industries (EIIs). Based on an international survey conducted under IEA IETS Task 22, responses from 29 experts highlight growing interest in AI applications such as predictive maintenance, demand forecasting, and process optimization. While AI is perceived as a key enabler of sustainability, most implementations remain in pilot phases due to high costs, integration complexity, and workforce skill gaps. Climate resilience is recognized but remains a secondary focus compared to energy efficiency. The findings also reveal a strong link between supportive policy environments and digital readiness, emphasizing the need for coordinated regulatory and technological efforts. This study contributes to the literature by connecting industrial stakeholder perspectives with broader digitalization and decarbonization agendas, offering insights to guide future research and policy development for a more resilient and sustainable industrial sector.

Keywords: Artificial Intelligence (AI), Digitalization, Climate Resilience, Energy-Intensive Industries, Energy Adaptation

Energy Efficiency Optimization in Plastic Pyrolysis: A Data-Driven Modeling Study

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Abstract. Plastic pyrolysis is a promising technology for converting plastic waste into valuable products such as bio-gas, bio-oil, and bio-char. This paper presents a computational model that simulates plastic pyrolysis at various heating rates, emphasizing optimizing energy efficiency. Using a MATLAB-based computational approach, we model the thermal decomposition of plastics and analyze the impact of different heating rates (1 °C/s, 10 °C/s, 20 °C/s, and 50 °C/s) on energy consumption and the yield of pyrolysis products. This study demonstrates that the heating rate plays a significant role in yield distribution and the overall energy efficiency of the pyrolysis process. The findings aim to support kinetic modeling practices and energy efficiency assessments in thermochemical waste-to-energy systems, particularly in contexts where energy optimization and sustainability are prioritized.

Keywords: Plastic pyrolysis, Energy Efficiency, MATLAB Simulation.

Globally Optimal Scheduling for Industrial Energy Cost Reduction Under Dynamic

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Abstract. Industrial manufacturing processes, particularly energy-intensive batch operations, face significant challenges due to volatile electricity prices and stringent sustainability requirements. This paper proposes a data-driven batch scheduling optimization framework designed to minimize electricity costs by aligning high-resolution energy consumption profiles with dynamic electricity pricing. The methodology integrates synthetic data generation, precise cost modeling at 10-second resolution, and a rigorous combinational optimization algorithm that ensures optimal scheduling solutions within discrete intervals. Validation through a real-world case study from a Danish foundry demonstrates substantial cost savings, achieving an overall weekly electricity expense reduction of approximately 16,783 DKK across multiple batches. The proposed approach distinctly advances existing literature by guaranteeing global optimality, explicitly incorporating real operational constraints, and employing realistic industrial data for validation. This research provides practical, robust decision-support capabilities, enabling industries to effectively navigate market fluctuations, reduce operational costs, and enhance environmental sustainability without additional capital investment.

Keywords: Energy cost optimization, Dynamic electricity pricing, Industrial batch scheduling, Data-driven optimization, Sustainability.

Energy Informatics for Electric Vehicles and Mobility Systems

The Irish Highway Network: A Novel Test Instance for the Charging Station Location Problem

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Abstract. Electric Vehicles (EVs) are one of the most promising sustainable transportation solutions but require efficient refueling strategies to complete their long-distance journeys. When addressing the charging station location problem (CSLP), a well-developed network enables operators to strategically locate charging stations, efficiently mitigating range anxiety among EV drivers, and supporting the wider adoption of EVs. This study provides a description of the methodology for creating a real-world CSLP instance based on the Irish highway network and traffic count data. We capture key settlements and intersections from the Irish national road map, and construct the Irish highway network as a graph, made up of motorways, national primary roads, and national secondary roads. Applying the Lincoln MPO Travel Model, we estimate the number of EV traffic flows between all origin-destination pairs based on traffic counts on each road segment. This study evaluates the Irish highway network test instance by analyzing graph-based metrics and compares its characteristics with other widely-used CSLP instances from the literature. The results of the comparative analysis indicate that the proposed Irish highway network is a well-connected and favourable test instance to evaluate CSLP optimization models.

Keywords: OR in Energy · Sustainable Transportation · Charging Station Location Problem · Irish Highway Network

Enhancing EVRP Benchmark Instances with Energy Estimates

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Abstract. The increased use of electric vehicles (EVs) to deliver goods in the last mile of the delivery process means that there is a need for more realistic energy consumption models. Benchmark instances of the electric vehicle routing problem (EVRP) currently use an energy consumption model of one unit of energy consumed for every one unit of distance travelled. The underestimation of energy consumption can lead to problems in the routes, in the life cycle and cost benefit analysis of EVs, and their demand and impact on the grid. We use a structured approach to enrich current benchmark instances, following the CRISP-DM data mining framework. This paper provides insights into explanatory variables that impact energy consumption, and provide a replicable methodology to create realistic benchmark instances using real world data.

Keywords: Energy consumption · EVRP · Sustainable Transport · Data enrichment

Economic and Environmental Benefits of Centralized MILP Optimization of EV Fleet Charging

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Abstract. With the goal of achieving climate neutrality, many European countries are accelerating the electrification of the transport sector—one of the major contributors to CO_2 emissions. To reduce costs and improve sustainability, they are increasingly integrating electric vehicle (EV) fleets into the power grid. However, this integration introduces challenges such as increased pressure on grid stability, making coordinated charging strategies essential to fully realize the benefits of EV deployment. To address the EV fleet charging scheduling problem, this study develops a centralized optimization model based on Mixed-Integer Linear Programming (MILP), a widely adopted and flexible approach. While existing research typically focuses either on cost or emissions, and often within the scope of a single-country case study, this paper presents a comparative analysis of both cost and sustainability outcomes across five European countries: Croatia, France, Germany, Sweden, and Poland. By evaluating smart charging potential under uniform operational assumptions, the study highlights how the effectiveness of EV integration varies significantly depending on national electricity market structures and energy mixes. The results provide valuable insights for policymakers, energy planners, and fleet operators, demonstrating the importance of tailoring EV strategies to specific national contexts.

Keywords: EV fleet management, EV integration, EV charging optimization, demand response, cross-country analysis, cost analysis, sustainability analysis

Electric Vehicle based virtual electricity network (EVEN) solution for performance enhancement in distribution networks

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Abstract. Large-scale electric-vehicle (EV) uptake is challenging the power grid due to a lack of sufficient hosting capacity. Most smart-charging studies still treat EVs as stationary loads in one location and ignore their mobility. This work closes that gap by evaluating an EV-based virtual electricity network (EVEN) that lets vehicles charge at one feeder and discharge at another. We formulate a comprehensive framework that combines inter-network energy-delivery optimization, stochastic time-series hosting capacity analysis, and battery-degradation assessment. The approach is tested on two real-world distribution systems: a voltage-constrained 50-bus rural residential network and a capacity-rich 76-bus industrial network. Simulation results reveal that shifting only 10 % of the evening demand from the rural to industrial network cuts the rural undervoltage index by roughly 80 % and weekly violation counts by 65 %, while adding no more than two minor violations upstream. At this level, average yearly battery-cycling degradation rises modestly from 0.4 % to 0.8 %. The study thus demonstrates EVEN as a cost-effective, scalable alternative to physical reinforcement and provides the first integrated assessment linking network-level benefits with battery-health impacts.

Keywords: Electric Vehicle, Hosting Capacity, E-mobility, Grid Integration.

Variational Quantum Eigensolver-Based CaaS Business Model for V2G

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Abstract. In electric vehicles (EV) ecosystem, Charging-as-a-Service (CaaS) with subscription models has emerged as a promising approach to optimize EV charging infrastructure while ensuring cost-effectiveness and accessibility. However, traditional optimization methods struggle to handle the complex, dynamic nature of large-scale EV charging networks. This paper proposes a novel Charging -as-a-Service (CaaS) business model leveraging the Variational Quantum Eigensolver (VQE) algorithm to optimize energy management in Vehicle-to-Grid (V2G) systems. By integrating quantum computing with V2G infrastructures, the proposed model addresses the increasing computational complexity of large-scale energy optimization in smart grids with high EV penetration. The VQE algorithm is utilized to minimize the system Hamiltonian representing energy cost and grid stability parameters, offering superior performance over classical optimization approaches in terms of scalability and convergence. The paper explores the integration of quantum computing to enhance CaaS subscription models by leveraging quantum optimization algorithms for real-time charging scheduling, demand forecasting, and grid resilience. The CaaS model enables stakeholders including EV fleet operators, energy providers, and grid managers to access quantum computing resources on demand, reducing upfront investment and enabling adaptive, high-performance energy decision-making. Simulation results demonstrate the feasibility and benefits of the quantum-enhanced model, including improved grid resilience, reduced peak load, and enhanced economic returns for participants. By harnessing the power of quantum computing, this study aims to revolutionize EV charging by enabling faster decision-making and improved resource allocation.

Keywords: Charging-as-a-Service, EV energy scheduling, quantum hamiltonian, subscription tiers, V2G, variational quantum eigensolver

Multi-Agent Systems and Local Market Coordination

Towards ICT-Enabled Multi-Agent based Operations in Local Energy Communities: A Proof of Concept

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Abstract. The growing decentralization of energy systems demands scalable and flexible coordination of distributed generation, energy storage, and demand-side flexibility across local energy communities. In this work, the existing agent-based planning system MASSIVE, which includes a local energy market, is extended and tested for use under real boundary conditions. Each agent represents either a single energy generation, conversion or storage component or an aggregate of multiple assets, which can be a simulation model or a physical hardware configuration. All agents communicate via a lightweight, MQTT-based layer, enabling modularity, interoperability, and real-time responsiveness. Within the MASSIVE framework, agents participate in a local electricity market by submitting bids that reflect their current operational constraints and preferences. During the market-clearing process, the aggregated bids are used by the marketplace to determine optimized setpoints. The resulting setpoints are then transmitted as control signals to physical assets. The applicability of these control signals is validated through a series of experiments involving real hardware, with consideration of technical and safety constraints. Furthermore, a battery energy storage system was successfully integrated into the live market environment, where it received and accurately followed real-time setpoints generated through the market-clearing process. The findings of the study demonstrate that the decentralized, agent-based market coordination model facilitates flexible integration of physical energy systems. The framework features plug-and-play functionality, heterogeneous control strategies, and interconnection across regions, which collectively offer a robust path to smart energy communities.

Keywords: Decentralized Optimization · Multi agent system · Local energy community · Market-based Coordination · Smart area · Real world hardware connection · Cloud based optimization.

A Peer-to-Peer Energy Management Model

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Abstract. We present a linear optimization model for peer-to-peer energy exchange for residential homes, taking into account heterogeneous consumption patterns and shared battery storage. The model supports intra-group trading among households within the same building, as well as inter-group trading between different buildings. Energy usage data from Icelandic households and meteorology data for the same period were used to simulate a scenario with two groups of users, where we study the effects of direct trading within and between groups. Our simulations indicate that most of the cost savings arise from intra-group trading rather than inter-group exchanges. The sensitivity analysis of battery maintenance costs suggests that this parameter must be carefully estimated for practical implementation.

Keywords: Peer-to-peer energy trading · Optimization · Battery storage · Solar photovoltaic production

Agent-based Flexibility Aggregation for a Distributed Redispatch

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Abstract. Integrating the flexibility of small-scale assets into the redispatch process is a necessary measure for the reliable operation of future energy systems with high shares of renewable energy, flexible loads and battery storages, especially at low voltage levels. Market-based procurement of redispatch flexibility from such assets is a useful complement to the existing process, enabling a scalable solution that reduces complexity for grid operators by decentralizing operations and pooling assets through aggregators. We present a novel flexibility model for household-level assets that is tailored to this use case. The model provides fundamental features and principles, but the calculation method may differ for different asset types. This is demonstrated by detailing the calculation methods for battery storages and heat pumps. The model enables efficient local computation on edge hardware, and can be used to generate optimized aggregated redispatch offers in a flexibility market. Intelligent aggregation facilitates offers that leverage the heterogeneity of the asset pool, thereby conferring a substantially greater degree of flexibility compared to that achievable through individual flexibility offers. The conceptual extension to other types of flexible plants is planned for future research.

Keywords: decentralized redispatch · small-scale flexibility · multi-agent system

A Visualization Framework for Exploring Multi-Agent-Based Simulations: Case Study of an Electric Vehicle Home Charging Ecosystem

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Abstract. Multi-agent-based simulations (MABS) of electric vehicle (EV) home charging ecosystems generate large, complex, and stochastic time-series datasets that capture interactions between households, grid infrastructure, and energy markets. These interactions can lead to unexpected system-level events, such as transformer overloads or consumer dissatisfaction, that are difficult to detect and explain through static post-processing. This paper presents a modular, Python-based dashboard framework—built using Dash by Plotly—that enables efficient, multi-level exploration and root-cause analysis of emergent behavior in MABS outputs. The system features three coordinated views (System Overview, System Analysis, and Consumer Analysis), each offering high-resolution visualizations such as time-series plots, spatial heatmaps, and agent-specific drill-down tools. A case study simulating full EV adoption with smart charging in a Danish residential network demonstrates how the dashboard supports rapid identification and contextual explanation of anomalies, including clustered transformer overloads and time-dependent charging failures. The framework facilitates actionable insight generation for researchers and distribution system operators, and its architecture is adaptable to other distributed energy resources and complex energy systems.

Keywords: Multi-agent simulation, data visualization, electric vehicles, dashboard, smart grid, emergent behavior

Policy, Metrics, and Infrastructure Performance

Proper definitions of micro grid metrics are needed! – a generalizable framework

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Abstract. The rapid adoption of renewable energy and energy storage technologies has accelerated the deployment of micro grids (MGs), highlighting the need for clear, standardized metrics to evaluate performance. Current definitions of several metrics for MGs vary widely, often ignoring key aspects such as internal losses, storage dynamics, and grid interactions, limiting comparability and practical applicability. This paper presents a comprehensive set of twelve well-defined metrics ranging from 0 to 1, that are inherently aligned with energy conservation principles and explicitly capture system losses. Synthetic yet realistic use case scenarios are used to demonstrate their flexibility and suitability for different technological and regulatory contexts. The results emphasize clarity, consistency, and practical relevance, laying the groundwork for broader empirical validation, standardization, and regulatory integration. Future work should focus on approximation methods to deal with real-world measurement limitations.

Keywords: metrics · key performance indicators · micro grid · energy storage system

Solar-Geothermal Power "HGS-ORC" System for Energy Co-generation: Energy, Economic and Environmental analysis

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Abstract This study focuses on modeling a power and heat generation system utilizing an Organic Rankine Cycle (ORC) power plant, with the geothermal source of Hammam Debagh in northeastern Algeria serving as a case study. The ORC geothermal power plant is integrated with a solar Fresnel Lens Reflector and a parabolic Trough collector system, creating a hybrid geothermal solar ORC system (HGS-ORC), which is linked to a heating application system for district heating and drying purposes. An analysis of thermodynamics, energy, and exergy was conducted for four potential system configurations. The analyzed configurations include the basic HGS-ORC, two HGSORC setups without a recuperator—one with a mass flow control system for the working fluid and one without—and two additional HGS-ORC setups with a recuperator, also with and without a mass flow control system. A study was conducted to analyze the economic and environmental aspects of various system configurations, utilizing design data as well as local and global economic and environmental factors. The results show that the HGS-ORC configuration equipped with recuperator and control system has the best energy, economic and environmental performances. The estimated annual production of this configuration is about 10 GWh of electricity and more than 76 GWh of heat available for heating and drying. Based on a conventional power plant working with coal fired as heat source, the avoided CO2 emission by this configuration is about 12.84 t CO2/h.

Keywords: ORC power plant, Fresnel Lens Reflector, Parabolic Trough Collector, hybrid geothermal solar ORC

Towards the Integration of Data Space Technology in Hydrogen Research Workflows

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Abstract. The increasing importance of hydrogen in the clean energy transition highlights the critical need for secure, interoperable, and efficient data management within research environments. Many hydrogen laboratories still rely on fragmented, manual, and non-standardised data exchange practices that hinder interoperability, traceability, and collaboration. This paper presents a tailored framework that integrates key components of Data Space technology specifically the International Data Spaces Association (IDSA) connector into hydrogen research workflows. A Minimum Viable Data Space (MVDS) architecture is designed and deployed using a real-world use case from a hydrogen research lab. The approach includes mapping laboratory operations to Data Space principles, implementing containerised connectors, and validating the setup through an experimental data exchange scenario. The results demonstrate a practical and scalable pathway for modernising laboratory data infrastructure, enhancing collaborative research, and advancing Europe's digital and sustainable energy goals.

Keywords: Data Spaces · Data Exchange · Data Management · Hydrogen · Research Infrastructure · Energy Data Space

Comparison of Outages Trends and Statistics in Nordic Countries Across Distribution Networks and their Impacts

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Abstract. This research compares the frequency and duration of outages within distribution networks for Nordic main land countries (Sweden, Denmark, Finland, and Norway). In addition, this paper focuses on planned and unplanned outages for low- and medium-voltage networks; the consequences of outages for distribution networks and companies; and the level of discomfort experienced by consumers during both planned and unplanned outages. This study highlights the countries with the highest incidence of outages by collecting data from their official reports, compares the frequency and duration of unplanned outages, focuses on SAIFI, SAIDI, and CAIDI-based outage indices, and examines their outage trends.

Keywords: Unplanned and planned outages · Distribution network · Outages trends.

Managing Risk in Distribution Systems with Solar Generation: A Case Study Using the MATPOWER Optimal Scheduling Tool

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Abstract. The increasing integration of renewable energy sources, particularly solar power, introduces variability that poses significant challenges to power system reliability. This research addresses the management of solar generation uncertainty in a distribution system using real data from the E.W. Brown Universal Solar Facility and electricity demand (load) data in Kentucky, U.S.A. The objective is to determine the amount of reserves to mitigate operational risks and maintain system stability under different uncertainty scenarios. We simulate the expected dispatch over 24 hours by solving a multi-period, stochastic, security-constrained DC optimal power flow (SCOPF) using the MATPOWER Optimal Scheduling Tool (MOST). Unlike traditional unit commitment models, we assume all generators remain continuously active throughout the dispatch horizon. To highlight the role of reserves, we compare four different operational cases. The results underscore the importance of reserves as a fundamental tool for managing renewable energy variability and ensuring dispatch reliability, denoting that optimal dispatch must balance supplying demand, maintaining sufficient reserves to handle uncertainties, and minimizing operational and financial risks.

Keywords: Stochastic dispatch · optimal power flow · renewable energy sources · uncertainty · reserves

Smart Energy Management System With Individual Load Monitoring

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Abstract. As household energy costs rise, consumers need intelligent solutions to monitor and optimize electricity usage. This paper presents a smart IoT-based energy management system that enables real-time tracking of individual appliances through an intuitive mobile app, web dashboard, SMS and offline interface. The system empowers users to view detailed usage trends, datalogging, set custom power thresholds for devices, and establish cost limits to prevent budget overruns. With remote control capabilities via app, web, or SMS, even without internet, the solution helps households identify wasteful consumption, automatically alert users about excess usage, and proactively manage devices. Considering India's 294 million households, even a modest conservation of 1 unit per home could save 294 million units daily. By combining granular energy insights with flexible control options, our system aims to reduce electricity bills, prevent appliance overload, and promote sustainable energy habits at a large scale. Such widespread adoption would not only support India's sustainable development goals but could fundamentally transform national energy conservation efforts. The system responds to the nation's changing energy landscape by turning every household into an active participant in responsible energy use through awareness and actionable control.

Keywords: IoT · Energy Monitoring System · Energy Conservation · Wireless Control · Multi-platform Alerts

Smart Building Systems and Semantic Data Integration

Towards a Taxonomy for Application of Machine Learning and Artificial Intelligence in Building and District Energy Management Systems

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Abstract. Building and district energy management increasing requires advanced control strategies. For several tasks that arise, Machine Learning (ML) and Artificial Intelligence (AI) have found widespread application, but often the interaction with existing elements and the integration into the productive system are done in a rather unsystematic way. Thus, one faces problems concerning interface design, data requirements and reliability/trustworthiness.

In order to improve this situation, we outline the general control structure of such systems, review key concepts from ML/AI and discuss approaches for conventional high-level control. This is followed by a literature review on ML/AI applications for energy management.

Based on the systematics and the literature findings, we establish a taxonomy for the integration of ML/AI methods for energy management, which leads as a main result to a quick comprehensive for such applications, taking into account both charactistics of the method and the affected elements of the system. This is supplemented by a quick guideline for choice of an appropriate method and for subsequent evaluation. The target readership are control engineers who would like to get a systematic overview of ways to integrate ML/AI methods in their, and data scientists who want to get a better understanding for main tasks and challenges for applying their tools for control tasks.

Keywords: Taxonomy · Control · Energy Management · Buildings · Districts · Optimization · Machine Learning · Artificial Intelligence.

A Dynamic Semantic Data Modeling Approach: Application to Flexible HVAC Zones

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Abstract. The semantic data model (SDM), which is considered a foundation for uniting data that are currently dispersed individually, was not envisioned to change intrinsically during daily use. Thus, the SDM needs to adapt to such changes for more advanced real-time control using dynamically changing spatial information. Based on these issues, the purpose of this study is to propose a method for creating a dynamically changing SDM with examples. Specifically, a method for describing an SDM that reflects the changes in the HVAC zones of each air conditioner owing to the movement of partitions and the operation status of the air conditioners is proposed. The changes in the SDM are classified into two types: changes in the graph structure and addition of telemetry data. As an example of application which associates with the dynamically changing SDM, a method for estimating each changing HVAC zone was proposed and the results were analyzed. Although the changes were observed in the HVAC zones, some cases were difficult to consider in practically. However, the results show the possibilities for more sophisticated estimation methods. As a case study in constructing an information system incorporating a dynamic SDM, a prototype was developed using a physical model. The system encompasses the sensing of partitions and occupants within the model, data integration to the SDM, and display of application outputs. This system was analyzed and compared with actual smart building information systems.

Keywords: Semantic Data Model, Dynamic Change of HVAC Zones, Data-Driven

Leveraging Generative AI and semantic data for improved operation of a real-life building

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Abstract. The operation of modern buildings generates large volumes of sensor data that, if effectively utilized, can significantly improve energy efficiency and fault detection. However, conventional fault detection and diagnosis (FDD) systems often rely on rule-based methods that lack context-awareness, generate excessive false alarms, and demand expert interpretation. This paper presents a novel framework that combines Large Language Models (LLMs), time series data, and semantic knowledge graphs to enhance building operation and diagnostics. The approach is implemented and evaluated in the ZEB Laboratory, a full-scale zero-emission building and research infrastructure in Trondheim, Norway. The proposed system integrates structured sensor metadata from a Neo4j-based knowledge graph with real-time measurement data from an InfluxDB time-series database. An LLM (GPT-4o) processes this data to detect anomalies and generate contextual explanations and recommended actions in natural language. One exemplary room serves as the primary testbed, showcasing how knowledge-driven reasoning enables accurate, actionable alerts with reduced false positives. Test scenarios demonstrate the framework's ability to identify faults and guide operational decisions. Structured outputs support seamless dashboard integration and potential for automated control. This work shows how generative AI combined with semantic metadata and real-time data streams can transform building management into a more intelligent, interpretable, and proactive process.

Keywords: generative AI, semantic data, building operation, anomaly detection

Data-Driven Optimal Air-Balancing Control for Multizone Ventilation Systems with Design-to-Operation Adaptation

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Abstract. Accurate air-balancing control is important for maintaining indoor air quality and reducing fan energy consumption in multizone ventilation systems. While data-driven approaches can outperform conventional control methods, their performance depends on their access to large volumes of high-quality operational data. To address this limitation, this study proposes an ANN-based optimal air-balancing strategy that bridges the design and operational phases. A physics-based duct network model was developed using Modelica to generate synthetic operational data. An artificial neural network (ANN) surrogate was then trained to capture the nonlinear actuator–airflow relationship. A hybrid optimization algorithm combining improved particle swarm optimization and Adam was developed to compute the optimal combinations of fan frequency and damper positions while satisfying the operational and energy-saving constraints. Simulation results benchmarked against the ASHRAE Guideline 36 trim-and-respond sequence show that the proposed strategy delivers more accurate air balancing with improved energy efficiency. To assess the robustness to parameter drift across project phases, both uniform and random perturbations are applied to the physical model. Fine-tuning the ANN with as little as 3% of new operational data restored, and often exceeded, the accuracy of the model retrained from scratch. These results demonstrate that the proposed strategy enables high-precision, phase-resilient air-balancing control with minimal real-world measurement effort.

Keywords: Air balancing · Multizone ventilation system · ANN model · Transfer learning

Development of an LSTM-Based Model for High-Resolution Downsampling and Reconstruction of HVAC Chiller Flow Data

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Abstract. High-frequency time-series data from HVAC systems offer detailed insights into dynamic performance but incur substantial storage and processing burdens. This study presents an intelligent, deep-learning–based downsampling framework that simultaneously compresses data and preserves critical temporal features. Raw one-second measurements of chiller supply temperature and instantaneous flow rate are aggregated into multi-resolution feature sets (1 min, 30s, 20s, and 10s) using statistical descriptors, and a Long Short-Term Memory (LSTM) network is trained to reconstruct the original one-second flow profile from these low-dimensional summaries. Comprehensive evaluation—including storage efficiency and mean squared error (MSE) against ground truth—demonstrates that the 20s aggregation achieves the best trade-off, reducing average reconstruction error (MAE = 19.8 L/min, MAPE = 2.40 %) and peak deviation (146.4 L/min) while cutting storage requirements by an order of magnitude. The model also reduces MSE during rapid ramp-up peaks by approximately 12% relative to one-minute baselines and maintains high fidelity in steady-state regimes. These results confirm that LSTM-based downsampling can dramatically lower data volumes with minimal loss of high-frequency information, facilitating the use of high-frequency monitoring data in more scenarios such as FDD detection and optimal control.

Keywords: HVAC (Heating, Ventilation, and Air Conditioning), Long ShortTerm Memory (LSTM), High-resolution data

Prosumer Optimization and Energy Storage in Local Energy Communities

Evaluating the Potential for Developing Local Energy Communities in Sweden: Case Studies at Jättesten and Chalmers Campus

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Abstract. As the Swedish electricity system transitions to cleaner and more sustainable energy sources, local energy communities (LECs), comprising groups of consumers and producers who share locally generated energy and energy-related infrastructure, are emerging as a promising solution to support the power grid. This paper aims to quantitatively evaluate the potential of LECs to improve the efficiency and sustainability of the Sweden's electricity system. To this end, two real-world demonstration sites in Sweden are analyzed: Jättesten, representing a residential load, and Chalmers Campus, representing a commercial load. The key performance indicators considered in these case studies include total annual operating cost, self-consumption (SC), self-sufficiency (SS), and peak shaving capability. The results show that combining residential and commercial loads within a single LEC significantly improves overall performance by leveraging demand diversity. Participation in LECs can reduce annual operating costs by up to 14 %, improve SC and SS by up to 4 %, and lower peak power demand by up to 20 %. Moreover, the analysis underscores the potential for further gains through the greater integration of photovoltaics (PVs) and battery energy storage system (BESS).

Keywords: Local energy community · energy management system · renewable energy integration · energy transition· real-world demonstration.

Data-driven Correlated Uncertainty Sets for PV Generation and Electricity Demand

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Abstract. Local energy communities (LECs) are viewed as key actors in the future clean energy system. However, uncertainty is inherent in renewable energy generation and electricity consumption. Renewable energy sources (RES) like solar and wind can exhibit considerable variation in power generation depending on weather and other factors. Optimisation techniques like Robust Optimisation (RO) aim to take uncertainty into account. It is important to account for uncertainty in both domains - power supply and electricity demand to facilitate the participation of LECs in the clean energy transition. In this paper, we examine empirical time-series data from the building energy management system (BEMS) of a public university in Ireland (University College Dublin) to characterise the temporal correlation between photovoltaic (PV) power generation and electricity consumption. We propose a data-driven approach to construct correlated uncertainty sets for supply and demand data by partitioning the day into specific time-windows. This data-driven approach reduces the level of conservatism in RO models for LEC distribution network design and operation decision problems.

Keywords: energy community · renewable energy· correlated uncertainty · energy analytics · holistic optimisation

Battery Energy Storage Integration for BIPV Systems: A Multi-Scenario Economic Analysis and Optimization

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Abstract. The application of Building-Integrated Photovoltaics (BIPV) coupled with Battery Energy Storage Systems (BESS) in smart buildings is known as an effective solution to enhance the energy performance of buildings. However, the economic viability of these systems remains a complicated and challenging matter due to high upfront costs, variable market prices, and fluctuating energy and economic policy schemes such as Feed-int Tariffs (FiT) regimes. This study investigates the Life Cycle Cost (LCC) based optimum sizing of BESS for BIPVequipped residential buildings under multi-scenarios of FiT schemes and BESS market prices in Italy. For this purpose, a residential building equipped with the aforementioned energy systems is parametrically modeled and evaluated with key LCC indicators including Net Present Cost (NPC) and Saving to Investment Ratio (SIR) to elaborate the economic performance of BESS adoption and accurate cost-effective size optimization. The results reveal a reverse relationship between FiT rates and BESS market price with cost-effective BESS size due to high upfront costs imposed by higher BESS market prices and higher financial revenue for electricity export to the grid as a result of higher FiT rates, both discouraging BESS adoption and self-consumption. The results quantitively evaluate the impact of these economic factors considering various BESS market prices under low, medium, and high FiTs scenarios. Moreover, the results highlight the current high BESS market price is a major barrier to its adoption in the building sector under most FiT scenarios. Furthermore, this study identifies the economic viability thresholds of BESS market price in various FiT scenarios and provides techno-economic and policy implications to further incentivize and promote BESS application in buildings equipped with BIPV.

Keywords: Photovoltaics, Energy storage, Battery systems, Optimization, Life cycle cost

Scheduling Heat Pumps for Balancing Thermal Storage and Grid Export

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Abstract. This paper evaluates the operational performance of Smart Grid Ready (SG-ready) heat pumps integrated with rooftop photovoltaic (PV) systems for a single-family prosumer dwelling. A rule-based control logic is developed to dynamically determine the operating mode of the heat pump (Enhanced, Normal, or Off) as well as the room temperature setpoint based on the grid tariff, thermal requirements, and PV availability. In particular, the rule-based framework governs the routing of PV generation; deciding when to store excess as thermal energy and when to export to the grid. It also influences the amount of load drawn from the grid and at what time-of-day tariffs. Five different rules are considered spanning various combinations of SG-ready mode activation points and choice of room setpoints. Simulation of these five strategies over the winter period (December to February) for four cities – London, Oslo, Tokyo, and Berlin – is reported here. The dynamic use of SG-ready modes for the heat pump combined with setback temperature strategies and PV use reduces costs by nearly 13 to 50% in most studies, irrespective of location. The maximum savings are observed in the strategy that uses SG-ready modes and uses higher setpoints at night and lower setpoints during the day to utilize solar heat gain. Results underscore the influence of local climate, electricity tariffs, and solar availability on system performance. This study demonstrates that integrating rule-based control with SG-ready capabilities significantly improves flexibility and operational efficiency in PV-enabled residential heating systems.

Keywords: Smart-Grid-Ready heat pumps · Rooftop solar · Prosumers · Electricity tariffs

Grid-Oriented AI, Simulation, and Resilience

A data-driven analysis of unscheduled flows in the European power system

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Abstract. Cross-border electricity trading is becoming increasingly important in the European power system. Unscheduled power flows induce additional costs and may lead to congestion and impair power grid operation. In this contribution we provide a data-centric analysis of unscheduled flows in the Central European power grid. Using methods from explainable machine learning, we identify the main driving factors for unscheduled flows and quantify their impact. Unscheduled flows in the meshed part of the grid can be mainly attributed to transit or loop flows and well described by a linear model. The performance is substantially worse for unscheduled flows on bridges, with forecasting errors being the most important drivers. The loss of performance is probably due to data quality issues.

Keywords: Unscheduled Flows · Explainable AI · Transit Flows· Forecasting Errors.

Green Hydrogen under Uncertainty: Evaluating Power-to-X Strategies Using Agent-Based Simulation and Multi-Criteria Decision Framework

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Abstract. The transition toward net-zero energy systems requires scalable and cost-effective deployment of Power-to-X technologies, particularly green hydrogen production. Despite increasing investments, a critical research gap remains in dynamically assessing how different operational strategies affect the feasibility of hydrogen production under real-world energy market conditions. Most existing studies rely on static, techno-economic models and overlook actor interactions, infrastructure limitations, and regulatory complexity. This paper presents a novel modeling framework that integrates agent-based simulation with multi-criteria decision-making to evaluate green hydrogen production strategies using colocated wind and solar generation. Three operational strategies—grid-only, onsite-only, and hybrid—are applied across three electrolyzer capacity levels (10 MW, 50 MW, and 100 MW) within a Danish case study. Real electricity tariffs, emissions factors, and market data are used to simulate technical, economic, and environmental performance indicators. The results show that hybrid strategies consistently outperform grid-only configurations in terms of cost and emissions while maintaining stable hydrogen output. Although on-site-only strategies minimize emissions and costs, they fail to meet fixed production demands. This framework offers novel scientific contributions by modeling dynamic actor interactions and integrating system performance evaluation into strategic planning. Practically, it provides actionable insights for energy planners and policymakers designing resilient and efficient Power-to-X systems in renewable-rich contexts.

Keywords: Green Hydrogen, Operational Strategy, Agent-Based Modeling, Multi-Criteria Decision Making, Renewable Energy Integration.

Synthesizing Fault Localization Datasets

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Abstract. The reliability of power distribution networks is critical to maintaining the continuous delivery of electricity to all consumers and sectors of the economy. Fault localization plays a key role in minimizing downtime and repair costs. In recent years, a growing number of studies have leveraged machine learning techniques to enhance the precision and the speed of fault detection and localization. However, a major challenge remains: the scarcity of comprehensive datasets that capture the complexities of power system faults. This study addresses this limitation by developing an enriched dataset and proposing methods to mitigate overfitting, a phenomenon in which a model captures noise or patterns specific to the training data, impairing its performance on unseen data. By augmenting existing data with simulated fault scenarios, our framework improves robustness and generalizability, and reduces the risk of overfitting of machine learning models.

Keywords: Power System · Distribution System · Dataset · Machine Learning · Graph Neural Network · Fault Localization.

Machine Learning-Based Cyberattack Detection in Power Data

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Abstract. The broader context of this study lies in the growing importance of securing power systems against increasingly sophisticated cyberattacks. As power grids and other critical infrastructures become more digitized, the potential attack surfaces expand, making robust anomaly detection systems crucial. Smart homes, which increasingly rely on IoT-based devices, are particularly vulnerable to cyberattacks. These attacks can have serious consequences, such as breaches of privacy, property damage, and even physical harm. The growing use of these devices by consumers highlights the importance of protecting them as a key sociotechnical issue. This work is based on the findings of a previous study, where attacks on 10 smart home devices were simulated, identified visually in their power consumption data, and grouped based on similarities in their time series data. The primary objective of the present study is to develop and test various classical machine learning models for the automated detection of cyberattacks using power consumption data. Given that many of the IoT devices in this study are consumer-focused, the practical relevance of these solutions for real-world smart home environments is emphasized. The initial time series data is used to create new features which are well suited for real-time monitoring. The performances of various machine learning models are examined, and the best models in terms of time and performance are presented. The results indicate that Extreme Gradient Boosting is particularly well-suited for real-time anomaly detection in power consumption monitoring systems, offering both high accuracy and efficiency across different device types.

Keywords: Smart home security, cyberattacks, anomaly detection, IoT devices, consumer IoT, power consumption patterns, machine learning.

Optimization of Second-Life Battery Energy Storage System in Buildings With Photovoltaic Panels: A Norwegian Case Study

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Abstract. This study investigates the techno-economic feasibility of deploying a second-life battery energy storage system (BESS), using a school in Oslo, Norway, as a pilot case. A mixed-integer linear programming (MILP) model is developed to evaluate the performance of one to six second-life battery modules (40 kWh/20 kW each), integrated with on-site photovoltaic (PV) generation. Two operational strategies are assessed: a baseline case involving self-consumption and dynamic price optimization, and a local flexibility market (LFM) case that enables the system to provide capacity reserves for financial compensation. The model used real 2024 load and generation data to simulate energy flows and economic performance. Under the baseline scenario, a system with six second-life battery modules had a simple payback period of approximately 16 years. Participation in the LFM significantly improved economic outcomes, reducing the payback period between 5.2 and 8.3 years as activation rates varied from 80% to 20%. The findings indicate that second-life Battery Energy Storage Systems (BESS) can be economically viable in non-residential buildings, especially when integrated with participation in LFM Additionally, targeted subsidies and improved on-site solar self-consumption can enhance the attractiveness of these investments by offsetting capital costs and increasing the value derived from energy. These results underscore the potential of second-life batteries as a cost-effective storage solution and as providers of flexibility services for the grid. Implementing these systems in commercial settings could support broader energy transition goals by extending battery lifespans and promoting circular energy practices.

Keywords: Battery Energy Storage Systems (BESS), Second-life, PV generation, Dynamic Prices, Local Flexibility Market

Non-Intrusive Load Monitoring and Data Competitions

ADRENALIN: Energy Data Preparation and Validation for HVAC Load Disaggregation in Commercial Buildings

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Abstract. Accurately monitoring and managing energy consumption in buildings is critical for improving efficiency and reducing environmental impact. Non-Intrusive Load Monitoring (NILM) enables energy disaggregation from aggregate meter data, but disaggregating heating and cooling loads presents unique challenges due to their continuously variable nature and dependence on external weather conditions. This paper presents a structured methodology for preparing a dataset specifically designed for temperature-dependent load disaggregation in commercial and public buildings. The dataset includes energy consumption from multiple buildings across diverse climate zones, integrating sub-metered heating and cooling loads with weather data. A rigorous data cleaning and preprocessing pipeline was implemented to ensure consistency, including unit normalization, outlier detection, cross-meter validation, and alignment with meteorological data. The resulting dataset provides researchers with high-quality energy and weather time series, enabling the development and validation of NILM algorithms for HVAC disaggregation. By documenting the dataset preparation process, this work establishes best practices for handling real-world energy data, ensuring reliability and reproducibility. This paper serves as a reference for future dataset curation efforts in NILM and temperature-dependent load analysis.

Keywords: Non-Intrusive Load Monitoring (NILM), Load Disaggregation, Temperature-Dependent Energy Use, HVAC Disaggregation, Smart Buildings, Energy Data Preprocessing, Weather Data Integration, Public Building Energy Dataset

Comparison of Three Algorithms for Low-Frequency Temperature-Dependent Load Disaggregation in Buildings Without Submetering

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Abstract. Heating, Ventilation, and Air Conditioning (HVAC) systems account for a significant portion of global energy consumption, making their efficient operation critical for energy savings and demand-side management. Non-Intrusive Load Monitoring (NILM) techniques provide a promising approach for disaggregating HVAC loads from aggregate energy consumption using smart meter data. However, most NILM research focuses on high-frequency data, which is often impractical for large-scale deployment due to hardware and infrastructure constraints. This study addresses the challenge of temperature-dependent NILM using low-frequency data by evaluating three algorithms: Bayesian Disaggregation, Time-Frequency Mask Estimation, and BI-LSTM. The Bayesian approach models energy consumption as a probabilistic distribution to estimate HVAC loads, the Time-Frequency Mask method applies spectral transformations for enhanced signal separation, and BI-LSTM leverages deep learning to capture long-term energy dependencies. Using the ADRENALIN and AMPds2 datasets, we compare these models based on accuracy, computational efficiency, and applicability across residential and commercial buildings. The results indicate that the Time-Frequency Mask Estimation model provides the most consistent accuracy, while Bayesian Disaggregation performs well in environments with clear seasonal variations. The BI-LSTM model demonstrates stable performance but struggles with dataset inconsistencies. This study contributes to the field by providing a comparative analysis of NILM algorithms for low-frequency HVAC load disaggregation and offering insights into model selection for real-world applications. Future research should explore hybrid approaches that integrate spectral transformations with advanced deep-learning architectures to enhance NILM accuracy and generalizability.

Keywords: Non-Intrusive Load Monitoring, HVAC Disaggregation, Bayesian Estimation, Time-Frequency Mask, BI-LSTM, Low-Frequency Energy Data, Smart Meter Analytics

Advancing Non-Intrusive Load Monitoring: Insights from the Winning Algorithms in the ADRENALIN 2024 Load Disaggregation Competition

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Abstract. The ADRENALIN 2024 Load Disaggregation Challenge: Energy Use in Buildings aimed to advance non-intrusive load monitoring (NILM) by developing unsupervised machine learning models capable of separating temperature-dependent heating, ventilation, and air conditioning (HVAC) loads from total building energy consumption. Unlike traditional NILM approaches that rely on labeled training data, this competition required participants to design scalable and generalizable methods without access to appliance-level ground truth data. The top three solutions demonstrated three distinct methodologies: an adjusted Seasonal-Trend decomposition using LOESS (STL) model leveraging reference weeks for seasonal adjustments, a Gaussian Mixture Model (GMM) clustering-based approach, and a base load decomposition technique distinguishing operational and HVAC-related loads. The highest-performing model achieved an average Normalized Mean Absolute Error (NMAE) of 0.235, successfully capturing seasonal HVAC trends while maintaining scalability and robustness. The competition results highlighted key challenges in automating HVAC disaggregation, improving model generalization across diverse building types, and integrating additional contextual data sources. Future research should focus on self-supervised learning, multi-modal NILM techniques, federated learning for privacy-preserving disaggregation, and computational efficiency for real-time NILM applications. These advancements will be instrumental in enabling energy-efficient building management, demand response strategies, and smart grid integration.

Keywords: Load Disaggregation, NILM, HVAC, Unsupervised Learning, Building Energy Management

Lessons Learned from the ADRENALIN Load Disaggregation Challenge

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Abstract. Crowdsourced data science competitions have emerged as a powerful mechanism for advancing research in energy informatics, offering scalable pathways for developing machine learning solutions that enhance energy efficiency and smart building operations. The ADRENALIN Load Disaggregation Challenge addressed a central problem in energy analytics—non-intrusive load monitoring (NILM) of heating and cooling loads in commercial buildings—while emphasizing the importance of model generalization across different buildings. This paper presents a comprehensive reflection on the lessons learned from organizing and executing the ADRENALIN competition, including technical insights, organizational challenges, and recommendations for future energy data challenges. In addition to the ADRENALIN case, a comparative analysis is conducted with recent energy informatics competitions, including ASHRAE Great Energy Predictor III, BigDEAL 2022, CityLearn 2022, the Global AI Challenge, AIcrowd's Brick by Brick competition, and the NYSERDA RTEM Hackathon. This analysis identifies common challenges and effective strategies, such as the importance of dataset quality and preprocessing, the impact of evaluation metric selection, and trade-offs between large-scale open platforms (e.g., Kaggle) and research-oriented platforms (e.g., CodaLab, AIcrowd). Based on these insights, the paper outlines a set of best practices for designing energy data competitions, including multi-phase evaluation structures, clearly defined scoring frameworks, enhanced participant engagement strategies, and pathways for post-competition implementation to maximize real-world impact.

Keywords: Energy Data Competitions, Crowdsourced Data Challenges, Non-Intrusive Load monitoring (NILM), Energy Load Disaggregation.

Business Model Innovation in Data Competitions: Insights from the 2024 ADRENALIN Load Disaggregation Challenge

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Abstract. Data competitions have become an essential mechanism for fostering open innovation in domains such as computer vision, natural language processing, and energy informatics. Despite their growing prominence, the underpinning business models that sustain these competitions remain underexplored, leading to uncertain long-term adoption and limited value capture. This paper addresses these gaps by examining the 2024 ADRENALIN Load Disaggregation Competition as a case study of both technical and business model innovation within energy informatics. The research adopts an embedded single-case design, supported by multiple data sources and a comparative analysis with the digital gaming industry. Findings indicate that integrating multi-sided platform principles—derived from gaming ecosystems—can catalyze scalable Non-Intrusive Load Monitoring (NILM) solutions, enhance stakeholder engagement, and establish viable revenue pathways. Empirical results show that unsupervised NILM algorithms developed under zero ground truth constraints achieved NMAE values below 0.30, demonstrating high performance across diverse building types and climates. The study concludes that a hybrid revenue approach, combining sponsorships, IP licensing, and post-competition collaborations, enables sustainable operations beyond the typical prize-based model. These insights contribute to both academic literature and practical guidelines, illustrating how data competitions can evolve into robust, multi-stakeholder ecosystems with enduring economic and societal benefits.

Keywords: Business Model Innovation, Data Competitions, Load Disaggregation, Multi-Sided Platforms, Non-Intrusive Load Monitoring.

Practical Information

Conference Location

Main Campus, KTH Royal Institute of Technology

- Address: Brinellvägen 8, SE-100 44 Stockholm, Sweden
- Weblink: https://www.kth.se/en/om/kontakt/kontakt-kth-1.1947

The location of the conference room – H1, Teknikringen 33, Auditorium

- Entrance: Teknikringen 33, floor 3
- Room number: 2512; Code: H1; Floor: 05
- Building: H-house, Campus: KTH Campus
- Weblink: https://www.kth.se/places/room/id/2d17f88e-20f3-4163-81d4-612bc8e84f04?l=en
- Google Maps: https://maps.app.goo.gl/wd3Vx9i6EcsCX23s7

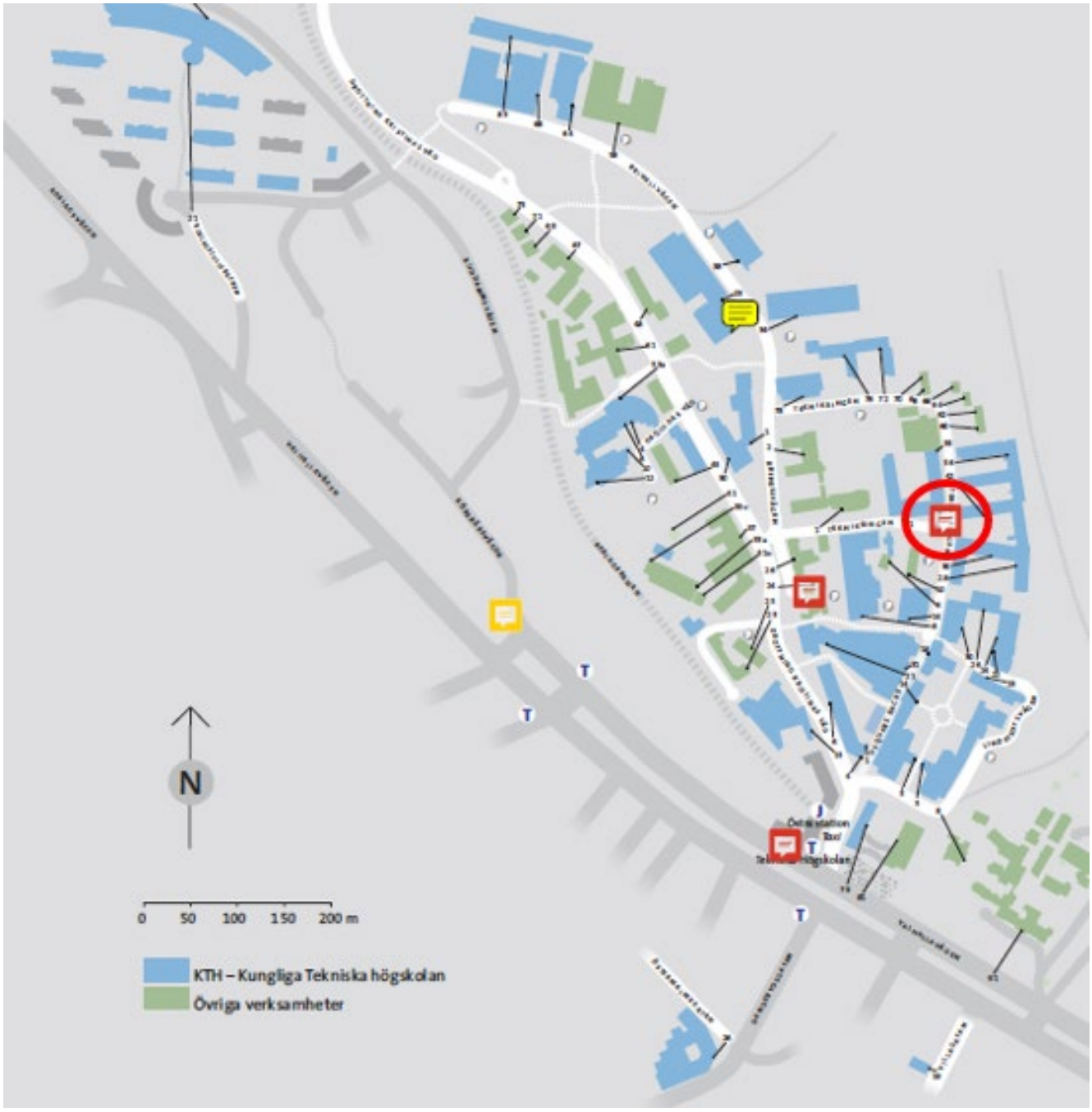
Gala Dinner Location

Restaurant Syster o Bror

- Address: Drottning Kristinas väg 24, 114 28 Stockholm
- Date and Time: 21 August, 18:30-21:00
- Weblink: https://systerobror.se/
- Google Maps: https://maps.app.goo.gl/xpXANKpTXU4w7snz9

Map of the Main Campus in Stockholm

- The conference venue location is shown in the circle on the map below
- Download the map via the link: https://www.nordicenergyinformatics.academy/_files/ugd/682403_cc4538322588427ebbf35a0c612d1efe.pdf



Travel Tips

The best means of transportation within Stockholm is public transport. Stockholm's public transport system, operated by **SL (Storstockholms Lokaltrafik)**, includes:

- **Metro (Tunnelbana)**: Fast and extensive, covering most of the city.
- **Buses**: Around 450 lines, many of which are electric or run on renewable energy.
- **Trams and Local Trains**: Great for suburban and regional travel.
- **Ferries**: Shuttle boats connect key points across the archipelago.

Other options include cycling, walking, renting a car, or taking a taxi or an Uber.

Contact Information

Email us if you have any questions regarding the conference

- Please make your email title start with "EIA Nordic 2025-Related matter"
- Email: contact@nordicenergyinformatics.academy