FEDECOM "Market Watch" Newsletter

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This 2nd Edition of the FEDECOM market watch newsletter explores:

- **Page 1:** Overview of the 2nd Edition and preview of the 3rd Edition content.
- **Page 2:** Quick reminder of FEDECOM exploitable results (ERs).
- **Pages 3-17:** Market watch results on each of the FEDECOM ERs.
- **Pages 18-20:** In the energy community news, non-ER specific.

Page 1. **Contents**

Contents

QUICK REFERENCE:

Page 2. **Reminder of FEDECOM Exploitable Results**

A quick overview of FEDECOM Exploitable Results, which serve as the basis for this newsletter.

FEDECOM ER	Type	Owner
ER1 FEDECOM Platform	ICT cloud-based platform enabling sector coupling and flexibility by integrating all the functionalities corresponding to previous ERs. Type: **Product / Service**	All Partners
ER2 MCDA Recommender based on LCA planning	Optimised Multi-Criteria Decision Analysis algorithm to provide an advanced energy planning tool. Type: **Service**	UCL
ER3 Energy Dispatch Model	Optimal model representing the energy dispatching including quantification of energy distribution losses, the characteristics of network assets and topology. Type: **Service**	FHG, UCL
ER4 Integrative Optimiser	Modelisation resource able to centralise all inputs from FEDECOM modules and users to provide optimisation services. Type: **Software / Service**	IMP
ER5 Grid Analytics & Diagnostics	Data driven grid analytics system able to measure and elaborate the grid parametres that can be used within the platform. Type: **Product**	HPOW, SUPSI
ER6 MPC Service	Algorithm to monitor and control the optimal thermal conditions in buildings taking into account the climate predictions and the expected energy demand. Type: **Product**	R2M
ER7 RES Production Models	Machine learning models able to formulate production forecasts depending on weather, number of assets involved in the EC, others. Type: **Product**	IMP
ER8 Storage Ageing Models	Software providing storage state estimations: both state of charge and state of health. Type: **Service**	FHG
ER9 Energy Demand Forecaster	Software forecasting the energy demand in the energy community based on buildings' parametres. Type: **Service / Process**	TEK, HWU
ER10 Demand Flexibility Estimator	Software modelling the opportunity of flexibility of each asset involved in the energy community. Type: **Product**	HWU
ER11 M&V Methodology	Methodology defining the data entry and measurement process in order to validate the energy savings and shared flexibility results. Type: **Process**	iLECO, SUPSI
ER12 Open Marketplace	Blockchain-based local marketplace coupling for energy and flexibility trading, including the functionalities of intra and inter-community peer-to-peer trading with smart billing and energy certificate issuance service. Type: **Product**	iLECO & GSY
ER13 Energy Gateway	Dedicated interfaces to integrate FEDECOM (platform backend) middleware with fieldlevel devices, with bidirectional communication mechanisms. Type: **Service**	FHG
ER14 Semantic Data Model	Ontology which enables semantic interoperability among the relevant modules comprising the FEDECOM Platform. Type: **Know-how**	TEK
ER15 Visualisation Tools	User-specific graphical interfaces for visualisation of relevant operation and performance data. Type: **Product / Process**	iLECO & HPOW

Page 3. **ER1: FEDECOM Platform**

Optimised Multi-Criteria Decision Analysis algorithm to provide an advanced energy planning tool.

REPORTS

- **(2022, Open Lab Athens):** **"The Participation Toolkit: Digital tools"** This guide developed by the gE.CO Living Lab H2020 project identifies open-source solutions and easy-to-use proprietary software built by communities for communities. It includes tools for online communications, project management and planning, as well as online courses and utility software for energy communities.
- **(2022, Energy Community Platform):** **"IT- and communication tools for energy communities"** In this report, the SCCALE 203050 H2020 project interviews energy communities to identify their IT and communication tools. The document compiles tools for internal organization, external communication, and engagement, aiming to inspire solutions for energy communities facing IT and communication challenges.
- **(2020, Co2mmunity):** **"How to increase Community Energy using the RENCOP-model"** This roadmap is for municipalities and regional actors in the Baltic Sea region to implement energy cooperative models and promote community energy.

EU Project Tools

- **SCORE** **developed an online "Prosumer-Investment Calculator"** for joint PV projects evaluates economic and legal implications, creates graphical forecasts of key performance indicators, and allows user input on project size and investment conditions. It leverages the principles of the most important existing business model framework for energy communities, namely: CSOP - Consumer Stock Ownership Plan (https://www.score-h2020.eu/contact/).
- **NOBEL GRID** **developed a web and mobile app for domestic and industrial prosumers** to monitor, control and manage their energy consumption and production and all the metrics and indicators that will support them to modify their energy behaviour to reduce emissions and electricity billing (Antonio MARQUÉS: amarques.etraid@grupoetra.com).
- **GAIA** **developed a web application called Building Manager App**, which monitors school energy consumption, correlates it with activities, and allows rules to be defined and enforced (Georgios MYLONAS: mylonasg@gmail.com).
- **WiseGRID** **developed the WiseHome App and the WiseCOOP Solution**. WiseHome provides real-time data, pricing incentives, and personalized consuler demand response contracts. WiseCOOP supports domestic and small businesses on energy retail, including net metering and demand forecasting (Antonio MARQUÉS: amarques.etraid@grupoetra.com).
- **FLEXCoop** **developed interfaces and apps for prosumers to monitor real-time demand data and aggregator events**. Features include energy demand monitoring, financial management, demand forecasting, notifications, compliance verification, controls, automation overriding options, & analytics dashboards (Silke CUNO: silke.cuno@fokus.fraunhofer.de).
- **MERLON** **developed a Prosumer App** for: secure billing services; interface for energy monitoring; analytics services for consumers and prosumers; & participation in flexibility markets (Antonis PAPANIKOLAOU: a.papanikolaou@hypertech.gr).
- **ENTROPY** **developed personalized mobile and social apps to provide real-time recommendations** based on users' behavioral profiling. These applications include personalized behavioral analysis, consumption, and cost efficiency motivation, retrofit suggestions, peer comparison, monthly projections, energy characterisation, and social media sharing for sharing data and achievements (Antonio SKARMETA GOMEZ: skarmeta@um.es).
- **PEAKapp** **developed a mobile app to raise consumer awareness regarding their energy consumption** and motivate households to adopt and sustain behavioural changes through different incentives including dynamic prices, social comparison, and serious gaming (Johannes REICHL: reichl@energieinstitut-linz.at).
- **Eco-Bot** **developed a chatbot app that monitors the energy consumption of specific appliances** and sends tailor-made energy saving recommendations to its users. The main target groups are Utilities and ESCO's. It seeks active user engagement towards improving their energy behaviour (Stephanos CAMARINOPOULOS: s.camarinopoulos@risa.de).
- **inBETWEEN** **developed an ICT platform for advanced energy services and home automation platforms**, enabling users to integrate connected devices and systems with energy analytics and optimization services for more energy-efficient daily routines (Margherita Scotto: margherita.scotto@rina.org).
- **BEcoop** **developed the "e-market tool" to support community bioenergy project development**, connecting supply chain stakeholders, and identifying potential partners / experiences (Yannis Kostopoulos: ikostopoulos@white-research.eu).
- **eCREW** **further developed GreenPocket's Energy Cockpit app** which provides transparency and interaction between utility, customer, and community webs, enabling users to monitor their energy consumption and identify potential savings (info@greenpocket.de).

Page 4.
ER2: MCDA Recommender based on LCA

Optimised Multi-Criteria Decision Analysis algorithm to provide an advanced energy planning tool.

PAPERS

- (2024, Elsevier): **"A data-driven framework for designing a renewable energy community based on the integration of machine learning model with life cycle assessment and life cycle cost parameters"** This research paper presents a data-driven framework for designing renewable energy communities in residential sectors, considering techno-economic challenges and environmental impact. It uses Homer Pro and Python tools to optimize photovoltaic, wind turbine, and battery systems. The framework's application is illustrated in a case study in Spain.
- (2022, Springer): **"A Participatory MCDA Approach to Energy Transition Policy Formation"** This chapter proposes a participatory MCDA approach to energy transition policy formation. The study aims to identify the most important criteria for energy transition policy formation and to evaluate the performance of different policy alternatives.
- (2021, Hindawi): **"MCDA for Renewable Energy Integration Design: For an Institutional Energy System Network"** This paper proposes a modified energy system in an existing building with integrated renewable energy using MCDA. Results of the survey in the building show that the best optimal hybrid configuration of the proposed location is the Gird-PV-Wind-based systems for the specific location based on SDG key techno-economic-environmental criteria.
- (2021, MDPI AG): **"MCDA for Renewable Energies: Research Trends, Gaps and the Challenge of Improving Participation"** This article reviews how social criteria and participation mechanisms have been incorporated into decision-making processes for renewable energy projects. It identifies and organizes 490 indicators that estimate social impacts into nine criteria. It highlights the challenges of improving expert consultation methodologies and broadening the participation of stakeholders when developing renewable energy initiatives and policies.
- (2021, IEEE): **"A Multi-Criteria Optimal Operation Framework for Renewable Energy"** This paper proposes a multi-criteria optimal operation framework for the Distributed Combined Microgrid (DCMG), considering coordinated scheduling of energy supply and demand. Multiple criteria are considered via a multi-criteria optimization (MCO).
- (2019; ICSD): **"Choosing energy supply options for rural communities: an MCDA approach"** This paper proposes an MCDA approach to determine the best energy alternatives for the supply of electric energy in rural areas. The study analyzes the extension of electricity grids and the use of local energy resources such as photovoltaic solar energy, wind energy, or hybrid systems, including local micro-grids.
- (2017, IEEE): **"A review on multiple criteria performance analysis of renewable energy systems"** This paper aims to review the applications of MCDA methods to the performance modeling and impact analysis of renewable energy systems, primarily in four relevant areas, including renewable energy planning and policy, renewable energy evaluation and assessment, renewable energy project selection and allocation, and renewable energy system environmental impact assessment.

ALGORITHM EXAMPLES

1. **Multi-Actor Multi-Criteria Analysis (MAMCA):** A participative MCDA method that has been applied to transition management in energy communities.
2. **Simple Additive Weighting (SAW):** A widely used MCDA method that has been used to evaluate clean energy technologies.
3. **Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS):** A method that has been used to evaluate clean energy technologies.
4. **Elimination Et Choix Traduisant la Realite (ELECTRE):** A method that has been used to evaluate clean energy technologies.
5. **VIseur Interactif de KOrdination des Resultats (VIKOR):** A method that has been used to evaluate clean energy technologies.
6. **COmplex PRoportional ASsessment (COPRAS):** A method that has been used to evaluate clean energy technologies.
7. **Analytic Hierarchy Process (AHP):** A method that has been used to evaluate renewable energy systems.
8. **Analytic Network Process (ANP):** A method that has been used to evaluate renewable energy systems.
9. **Decision-Making Trial and Evaluation Laboratory (DEMATEL):** A method that has been used to evaluate renewable energy systems.
10. **Fuzzy Analytic Hierarchy Process (FAHP):** A method that has been used to evaluate renewable energy systems.

Page 5. ER3: Energy Dispatch Model

Optimal model representing the energy dispatching including quantification of energy distribution losses, and the characteristics of network assets and topology.

THESES

- (2023, UCC): **Planning Studies for Distribution Grids with High Penetration of Distributed Energy Resources"** This thesis introduces innovative methods for transforming distribution network planning, including sharing economy concepts, technology-agnostic assignment of customers, location determination, and socio-economic implications for small-scale participants.
- (2022, Universitat Politecnica de Catalunya): **"Mathematical programming-based models for the distribution networks' decarbonization"** This thesis focuses on developing algorithms and optimization techniques for optimal sizing, allocation, and performance of new distributed generation-based networks in battery storage systems.

PAPERS

- (2023, Springer): **"Multi-Energy Complementation Comprehensive Energy Optimal Dispatch System Based on Demand Response"** The paper presents a Multi-energy Complementation optimal dispatch model utilizing Conditional Value at Risk, demonstrating that this system considers demand side response for more reasonable WP energy utilization.
- (2023, Elsevier): **"Multi-objective optimization of integrated energy system considering installation configuration"** This paper proposes a multi-objective optimization method for integrated energy systems (IES) focusing on gas turbine installation configuration. The method considers economy, energy consumption, and environmental benefits, reducing annual total cost, primary energy consumption, and CO2 emissions.
- (2023, Frontiers):**"Optimal dispatch of integrated energy systems considering integrated demand response and stepped carbon trading"** This paper proposes an optimal dispatch model for a multi-energy system that considers demand response and energy storage. The model uses a mixed-integer linear programming (MILP) method to optimize the energy dispatching of the system.
- (2023, Frontiers): **"Optimal scheduling of integrated energy systems with exergy and demand responsiveness"** The study presents a multi-objective optimum scheduling model and solution method for regulating customer load, supporting economic and environmental protection, and assessing synergistic growth in an integrated energy system, considering exergy efficiency and demand response.
- (2022, Springer): **"Optimizing design and dispatch of a renewable energy system with energy storage and demand response"** This paper proposes an optimization model for a renewable energy system with energy storage and demand response. The model generates an optimal design and dispatch strategy for a suite of technologies, subject to constraints on load shifting, peak shaving, power export agreements, and ancillary service markets.
- (2021, E3S): **"A Multi-objective Optimal Dispatch Method for Integrated Energy System Considering Multiple Loads Variations"** The paper presents a multi-objective optimization dispatching method for the Integrated Energy System (IES), considering energy efficiency, economy, and emissions. It establishes an IES model, simulates load variations, and uses genetic algorithm (GA) to find the pareto front. The method's effectiveness is verified through case studies.
- (2021, IEEE): **"Optimal dispatch of multi-energy complementary integrated energy system considering carbon emission trading"** This paper proposes an economic dispatch optimization model for renewable energy sources such as recovery systems and energy storage devices, with the goal of minimizing economic operating costs.
- (2021, IEEE): **"Optimal Model for Local Energy Community Scheduling Considering Peer to Peer Transactions via Local Electricity Market, Grid Transactions in Retail Market, and Battery Management Considering the Photovoltaic Production of Households"** This paper proposes an optimization model to schedule peer-to-peer transactions via local electricity market, grid transactions in retail market, and battery management considering the photovoltaic production of households.
- (2020, IEEE): **"Research on Optimal Dispatching of Multi-energy Flow System Considering Heat Network Loss under Different Optimization Objectives"** This paper proposes an optimal dispatching model for a multi-energy flow system that considers heat network loss under different optimization objectives. The simulation results show that the proposed model can effectively reduce the heat network loss and improve the energy efficiency of the system.
- (2019, MDPI AG): **"Optimal Dispatch of Integrated Energy System Considering Energy Hub Technology and Multi-Agent Interest Balance"** The paper explores the optimal dispatch of integrated energy systems, considering energy hub technology and multi-agent interest balance. It explores constraints, model solutions, and economic and environmental implications.

Page 6. ER4: Integrative Optimiser

Modelisation resource able to centralise all inputs from FEDECOM Platform modules and users to provide optimisation services.

THESIS

- (2021, HAL): **"Stochastic optimization for generation scheduling in a local energy community under renewable energy uncertainty"** This thesis proposes a stochastic optimization methodology for optimal generation scheduling in an urban microgrid to minimize operating costs and CO2 emissions. It addresses reserve scheduling, deterministic generation scheduling, and stochastic security constrained generation scheduling. The study also explores the contribution of energy storage systems to power reserve provision and the optimization of storage strategies based on the benefit target of the electrical network.

PAPERS

- (2023, Elsevier): **"Energy Communities: A review on trends, energy system modelling, business models, and optimisation objectives"** This paper reviews Energy Communities literature, focusing on detailed business models and objective functions. It highlights collaborations across nations and research fields, highlighting significant research opportunities in technical design, policy, and economics, particularly in multi-energy and sector-coupled systems, which are rarely considered in the energy community field.
- (2023, Springer): **"*Modelling RECs: assessing the impact of different configurations, technologies & types of participants*"** focuses on optimizing residential PV and battery systems in a P2P energy trading market, focusing on prosumer self-consumption and high-solar fraction PV sizing. Results show high-solar fraction PV sizing is most feasible for EC creation, despite lower investment costs and optimistic economic outputs.
- (2023, MDPI AG): **"*Optimal Scheduling of Controllable Resources in Energy Communities: An Overview*"** reviews mathematical models used for optimizing energy community operations, focusing on profit maximization and cost minimization. It identifies PV generation as a primary energy source. The study also explores stochastic and robust optimization models for electricity prices, renewable generation, and energy demand. It also discusses flexibility services using DR and the distribution of benefits among EC participants.
- (2022, Elsevier): **"Modelling of a multi-stage energy management control routine for energy demand forecasting, flexibility, and optimization of smart communities using a Recurrent Neural Network"** This paper presents an innovative algorithm for community energy management control, involving customers in energy trading by utilizing their energy flexibility. The model uses a matrix-based control system that considers individual and community priorities, shaping the aggregated network energy supply. The predictive system uses a recurrent neural network for real-time energy demand predictions. The model achieves a win-win situation, reducing energy demand by 21% during demand response events and decreasing electricity network interaction by 15%.
- (2021, MDPI AG): **"Modeling Energy Communities with Collective Photovoltaic Self-Consumption: Synergies between a Small City and a Winery in Portugal"** This paper analyzed three energy community configurations in a small Portuguese city using the Calliope framework. Results show that collective arrangements can increase photovoltaic capacity penetration and reduce electricity costs. However, centralized configurations have lower installation costs but are more sensitive to grid use costs. Additionally, key actors' self-consumption rates may decrease.
- (2020, IEEE): **"Optimized Operation of Local Energy Community Providing Frequency Restoration Reserve"** This article discusses the optimal operation of a local energy community (LEC) providing manual frequency restoration reserves and tertiary reserves, with electric vehicles and a battery energy storage system as FERs. The model's implementation and simulation results show significant impact on LEC profitability.
- (2019, Elsevier): **"Portfolio optimization of energy communities to meet reductions in costs and emissions"** This study enhances two open-source models using Pareto Optimization for costs and carbon emissions. It uses clustering algorithms to improve scalability and performance. The models are applied to a case study in Linz, Austria, revealing that while it's possible to reduce both objectives, the solutions for minimum costs and carbon emissions differ.
- (2018, Elsevier): **"Optimizing rooftop photovoltaic distributed generation with battery storage for peer-to-peer energy trading"** In this paper, the proposed optimization model investigates the economic benefits of rooftop PV-battery distributed generation in a peer-to-peer energy trading environment. It reveals that households with larger PV systems and battery storages can achieve up to 28% savings, but lower savings when PV penetration is high.
- (2014, ASHRAE): **"A Computational Framework for Low-Energy Community Analysis and Optimization"** This (direct download) paper presents a computational framework and reference implementation for LEC analysis and optimization, designed to automate repetitive tasks. The framework includes whole building simulation, community-wide optimization of distribution and supply, geospatial data, and data organization.

Page 7. ER5: Grid Analytics & Diagnostics

Data driven grid analytics system able to measure and elaborate the grid parametres that can be used within the platform

REPORTS

- (2020, IEA): **"Analytical Monitoring of Grid-connected Photovoltaic Systems"** This report emphasizes the need for collaborative efforts in transitioning to sustainable energy systems through the IEA Photovoltaic Power Systems Programme. It provides guidelines for monitoring and analyzing grid-connected photovoltaic (PV) systems, addressing challenges and opportunities related to PV technologies. The report emphasizes understanding PV system losses, new technologies' behavior, and their economic and technological impact for effective energy community planning. Recommendations for improving PV system performance and real-time monitoring align with energy communities' goals for optimized and sustainable energy generation.
- (2020, SIA Partners): **"Building the pyramid of grid analytics. The path to data-driven network planning and operations"** This report explores the energy industry's transformation, highlighting the growth of renewables, decentralization, and electrification. Network operators face challenges like grid capacity expansion, power flow uncertainty, and limitations of traditional methods. Grid analytics, a data-driven solution, is presented as a pyramid, encompassing layers like asset data, network models, operational data, automated grid calculations, and machine learning/artificial intelligence. The report highlights the importance of data quality and the need for gradual and inclusive change. Early adoption uses include load forecasting, renewable generation forecasting, frequency domain calculations, and fraud detection. The report also addresses cultural differences between safety-focused and fast-paced tech innovation, recommending gradual and inclusive changes. Legal frameworks also pose challenges, such as role separation limitations and cost and revenue mismatches. The evolving energy industry demands grid analytics for smarter decision-making and international cooperation.

PAPERS

- (2023, Springer): **"A Data-Driven Energy Management Strategy Based on Deep Reinforcement Learning for Microgrid Systems"** This paper proposes a data-driven energy management strategy based on prioritized experience replay soft actor-critic (PERSAC) for microgrid systems. The strategy is designed to improve the stability and economy of microgrids by controlling distributed generators and an energy storage system.
- (2023, Springer): **"Data-driven next-generation smart grid towards sustainable energy evolution: techniques and technology review"** This paper discusses the development of NGSG, focusing on intelligent control, agent-based energy conversion, edge computing, IoT enabled inverters, and agent-oriented demand side management. It explores the prospects and adaptation challenges of data-driven techniques in NGSG and highlights future issues.
- (2023, IEEE): **"Data-Driven Analytics for Reliability in the Buildings-to-Grid Integrated System Framework: A Systematic Text-Mining-Assisted Literature Review and Trend Analysis"** This systematic literature review examines machine learning methods for enhancing reliability in B2G-integrated systems. It collected nearly 10,500 papers from databases and used text-mining-assisted BERTopic-based topic modelling and statistical trend analysis techniques. The study reveals insights into state-of-the-art analytics and proposes future research directions, highlighting the importance of reliable analytics in B2G-integrated systems.
- (2021, Frontiers): **"Data Consistency for Data-Driven Smart Energy Assessment"** This paper highlights potential issues and solutions in power and energy systems, including generation, grid, and user sides, using recent and historical references. The context of this paper is based on the smart grid era, which has increased data availability for various applications, but its usability requires validation by experts. Data gathering and transmission must be verified for usefulness and consistency. Suitable procedures are needed to transform data into knowledge effectively.
- (2018, Springer): **"Big data analytics in smart grids: a review"** This paper introduces big data analytics and corresponding applications in smart grids. It discusses the motivation and potential advantages of implementing advanced data analytics in smart grids.

Page 8. **ER6: MPC Service**

Algorithm to monitor and control the optimal thermal conditions in buildings taking into account the climate predictions and the expected energy demand.

PAPERS

- (2024, Cornell University): **"Optimal Control of Renewable Energy Communities subject to Network Peak Fees with Model Predictive Control and Reinforcement Learning Algorithms"** This paper presents an optimal control framework for renewable energy communities (RECs) with controllable assets, aiming to minimize individual electricity bills. Comparing rule-based strategies with model predictive control and reinforcement learning algorithms, results show lower electricity bills and promising real-time control.
- (2023, Elsevier): **"Predictive control and coordination for energy community flexibility with electric vehicles, heat pumps and thermal energy storage"** This paper presents a two-stage energy management strategy, focusing on optimizing home energy management systems for electric vehicle charging and discharging, and applying predictive coordination to enhance grid flexibility. The method reduces operating costs and prevents load-shedding.
- (2023, IEEE): **"Distributed Noncooperative MPC for Energy Scheduling of Charging and Trading Electric Vehicles in Energy Communities"** This article presents a control strategy for optimal scheduling of an energy community consisting of prosumers and EVs. The strategy uses a rolling horizon control framework to improve energy allocation.
- (2023, Frontiers): "**Optimal Control of Renewable Energy Communities with Controllable Assets"** This paper proposes a generic formulation for optimal control of renewable energy communities (REC) with controllable assets, such as batteries. The electricity generated by the community members is redistributed using repartition keys.
- (2023, PLOS): **"Model Predictive Control of Consensus-Based Energy Management for Microgrids"** This paper proposes a consensus-based energy management system for microgrids using MPC. The proposed MPC algorithm is designed to optimize the energy consumption of the microgrid while ensuring that the energy demand is met.
- (2023, CET): **"Physically Consistent Deep Learning-Based Model Predictive Control for Community Energy Management"** This study introduces a Physically Consistent Deep Learning (PCDL)-based MPC for community energy management, incorporating building-to-grid interactions and renewable energy resources. The PCDL model estimates thermal load and indoor climate, reducing energy costs and maintaining comfortable indoor conditions. A simulation case study at Cornell University validates the effectiveness of the framework.
- (2022, Elsevier): **"Combined model predictive control and ANN-based forecasters for jointly acting renewable self-consumers: An environmental and economical evaluation"** This paper presents a Model Predictive Control (MPC)-based control design for minimizing electricity cost and CO2 emissions, utilizing Artificial Neural Networks for forecasting, and evaluating its economic performance.
- (2022, Springer): **"Energy Management Strategy Using Model Predictive Control for Power-to-Gas (PtG) System Integrated with Microgrid"** This paper proposes a model predictive control (MPC)-based energy management strategy (EMS) for a hybrid storage-based microgrid (μG) integrated with a power-to-gas system. The proposed EMS effectively controls the operation of the microgrid by maximizing the utilization of renewable power, proper control of the operating limits of the state of charge of storage, and balance in demand and supply.
- (2022, JSDEWES): **"The State of the Art in Model Predictive Control Application for Demand Response"** This review paper discusses the effectiveness of Model Predictive Control in optimizing demand response, comparing various optimization methods and discussing current research challenges and future directions.
- (2021, Hindawi): **"Robust Model Predictive Control for Energy Management of Isolated Microgrids"** This paper proposes a robust model predictive control (MPC) algorithm for energy management of isolated microgrids (IMGs) with renewable energy resources (RERs). The proposed MPC algorithm is designed to optimize the operation of the IMGs by minimizing the total cost of energy consumption.
- (2021, Elsevier): **"Model predictive control based robust scheduling of community integrated energy system with operational flexibility"** This paper proposes a unified scheduling model for Community Integrated Energy Systems (CIES) considers coupling characteristics, thermal storage capacity, and indoor temperature. A model predictive control (MPC)-based robust scheduling strategy enhances flexibility and uncertainty adaptability, resulting in better operation economy and robustness for real-time errors.
- (2021, MDPI AG): **"Model Predictive Control for the Energy Management in a District of Buildings Equipped with Building Integrated Photovoltaic Systems and Batteries"** The paper presents a MPC strategy for optimal energy management in a district with vertically placed Building Integrated Photovoltaic (BIPV) systems and Battery Energy Storage Systems. The strategy maximizes district autonomy and cooperation among interactive buildings.

Page 9. ER7: RES Production Models

Machine learning models able to formulate production forecasts depending on weather, number of assets involved in the EC, others.

PAPERS

- (2024, MDPI AG): **"A Machine Learning-Based Electricity Consumption Forecast and Management System for Renewable Energy Communities"** The study introduces a new method for managing community energy balance using Machine Learning techniques, specifically eXtreme Gradient Boosting (XGBoost), to forecast electricity consumption. The system reduces community electricity expenses and dependence on centralized grid energy, with better results for bi-hourly tariffs and high storage capacity scenarios.
- (2023, Springer): **"A flexible and lightweight deep learning weather forecasting model"** This study proposes a deep learning model for weather forecasting that can be used for renewable energy applications. It uses historical data from two London locations. Two Bi-LSTM recurrent neural network models were trained to make predictions in the next 24 and 72 hours. The first model predicted temperature at Kew Gardens with 73% accuracy, while the second predicted air temperature and relative humidity at Heathrow with 80% accuracy.
- (2023, Springer): **"Predicting Active Solar Power with Machine Learning and Weather Data"** In this paper, a predictive model for solar photovoltaic systems was developed using machine learning techniques. The model accurately predicted power output, allowing for better monitoring and estimation of solar energy in changing weather conditions. The model achieved a high R2 value of 0.87.
- (2022, Elsevier): **"A systematic review of machine learning techniques related to local energy communities"** This paper presents a conceptualization of a local energy community based on 25 projects and a literature review of machine learning algorithms for energy community applications. Results show supervised learning provides accurate forecasting models, while reinforcement learning offers control-related applications.
- (2022, Elsevier): **"Renewable energy management in smart grids by using big data analytics and machine learning"** This work discusses the benefits and challenges of big data analytics for renewable energy power stations. A framework is developed for predicting smart grid stability using five machine learning methods. Data from a decentralized smart grid system showed high accuracy, with models like penalized linear regression, random forest tree, decision tree, and convolutional neural network yielding 87% accuracy.
- (2022, Elsevier): **"Advances of machine learning in multi-energy district communities– mechanisms, applications and perspectives"** This study reviews artificial intelligence applications in carbon-neutral district communities, focusing on energy supply, storage, district demands, and management. It demonstrates supervised, unsupervised, reinforcement, and deep learning techniques, and their practical applications in renewable energy supply, hybrid energy storages, and district energy demand.
- (2022, MDPI AG): **"Machine Learning in Weather Prediction and Climate Analyses—Applications and Perspectives"** This paper analyzes 500 relevant scientific articles on machine learning methods in climate and numerical weather prediction, identifying common topics, methods, and countries. It concludes that machine learning will be crucial in future weather forecasting.
- (2021, Elsevier): **"Weather Prediction Using Machine Learning"** This paper introduces a system of information and statistics analysis algorithms has been developed to format effective weather forecasts. This approach helps insurers make decisions and addresses inconsistencies and inequalities in the weather forecast model.
- (2021, HAL): **"Machine Learning on Buildings Data for Future Energy Community Services"** The paper discusses the use of decision tree technique for predicting building consumption, photovoltaic production, and fault detection in a community, emphasizing the importance of these techniques for energy community service.
- (2021, IEEE): **"Forecasting of short-term PV production in energy communities through Machine Learning and Deep Learning algorithms"** This paper proposes a method for forecasting an energy cooperative's solar plant's short-term production using four Machine Learning and Deep Learning algorithms, providing high accuracy forecasts up to 6 hours, suitable for scheduling energy community supply and predictive maintenance.
- (2020, MDPI AG): **"Machine Learning Techniques for Improving Self-Consumption in Renewable Energy Communities"** This paper proposes data analytics modules to help community members schedule resources for electricity bill reduction. It uses advanced machine learning techniques and a new method to improve neural network forecasting performance. The techniques were tested on a pilot Renewable Energy Community in Belgium, showing no significant changes in consumption behavior.

Page 10. **ER8: Storage Aging Models**

Software providing storage state estimations: both state of charge and state of health.

PAPERS

- (2023, MDPI AG): **"Joint State of Charge (SOC) and State of Health (SOH) Estimation for Lithium-Ion Batteries Packs of Electric Vehicles Based on NSSR-LSTM Neural Network"** The paper presents a joint estimation method for SOC and SOH in battery packs using NSSR and LSTM neural networks. Validated using testbed data, the method achieves errors within 2.5% and 1.3%, respectively.
- (2023, MDPI AG): **"Combined State of Charge and State of Energy Estimation for Echelon-Use Lithium-Ion Battery Based on Adaptive Extended Kalman Filter"** This paper introduces a method for estimating combined state of energy (SOE) and state of charge (SOC) in a EULIB. It uses a third-order resistor-capacitance equivalent model, long short-term memory (LSTM), and an adaptive extended Kalman filter. The method improves accuracy by incorporating real-time optimization of Ohmic internal resistance, actual energy, and actual capacity parameters. The algorithm's accuracy is less than 1.19%, offering a new perspective for estimating SOE and SOC.
- (2023, Elsevier): **"Hybrid deep neural network with dimension attention for state-of-health estimation of Lithium-ion Batteries"** This study presents an end-to-end multi-battery shared hybrid neural network (NN) prognostic framework for SOH estimation for LIBs. It uses a CNN for feature extraction and selection, a suitable VLSTM for distinguishing subtle features, and a dimensional attention mechanism for weighting features. The CNN layer output data is fed into a VLSTM NN, and the attention mechanism assigns weights to each dimension. Experiments on three datasets from NASA, CALCE, and Oxford verify the method's effectiveness.
- (2021, IEEE): **"State-of-Charge and State-of-Health Estimation for Lithium-Ion Batteries Based on Dual Fractional-Order Extended Kalman Filter and Online Parameter Identification"** This paper discusses a method involving Dual Fractional-Order Extended Kalman Filter and Online Parameter Identification. The content emphasizes applications related to lithium-ion batteries, particularly in the context of energy communities.
- (2020, Elsevier): **"Energy storage and multi energy systems in local energy communities with high renewable energy penetration"** This study explores how a high-capacity residential district can self-consume its renewable electricity production, potentially fulfilling the concept of a "Renewable Energy Community." It explores the role of storage systems and polygeneration in renewable self-consumption, utilizing synergies among energy networks. The results show a multi-energy system, utilizing polygeneration technologies and energy storage, is the most cost-effective solution, with a 42 kWe CHP micro gas engine, 135 kWh battery system, and 2830 kWh hydrogen storage.
- (2020, Springer): **"Review of state-of-the-art battery state estimation technologies for battery management systems of stationary energy storage systems"** This paper reviews battery state indicators and suggests future developments for battery management systems in stationary energy storage systems. Lithium-ion batteries are crucial for renewable energy storage devices, but their design life and safety are key concerns. Battery management is essential, and state indicators like SOC, SOH, SOF, and SOT are widely used.
- (2020, IEEE): **"Machine Learning Applied to Electrified Vehicle Battery State of Charge and State of Health Estimation: State-of-the-Art"** This paper reviews battery state estimation methods using machine learning (ML) approaches like FNNs, RNNs, SVM, RBF, and Hamming networks. It compares their data quality, inputs and outputs, test conditions, battery types, and accuracy. The study also suggests training networks multiple times for optimal results. It recommends comparing networks with similar learnable parameters and identical data to ensure accurate conclusions about the quality of estimation techniques.

NEWS

- (2023, Analog): **"A Closer Look at State of Charge (SOC) and State of Health (SOH) Estimation Techniques for Batteries"** This technical article provides a review of SOC and SOH estimation techniques for batteries, focusing on lithium-ion cells. It discusses the importance of measuring SOC and estimating SOH, the technical environment specifications for coulomb counting, and estimation methods like the coulomb counting method, voltage method, and Kalman filter method. It also discusses commercial solutions and best-in-class algorithms.
- (2021, Hackernoon): **"Effectively Measuring State-of-Charge and State-of-Health with a Battery Management System"** This article discusses the importance of a battery management system (BMS) in ensuring battery security and longevity. It highlights the complexity of creating a BMS, the wide spectrum of battery chemistry, and the importance of choosing a battery that meets the system's specifications. It also provides an example of lithium-ion recharging.

Page 11. ER9: Energy Demand Forecaster

Software forecasting the energy demand in the energy community based on buildings' parametres.

PAPERS

- (2024, Elsevier): **"Evaluation of building energy demand forecast models using multi-attribute decision making approach"** This work presents a Gini Index based Measurement of Alternatives and Ranking according to COmpromise Solution (GI-MARCOS), a hybrid Multi Attribute Decision Making (MADM) approach for identifying the most efficient building thermal energy demand forecast tool. GI-MARCOS assigns meaningful objective weights to attributes in four phases, avoiding biases and providing a robust ranking of alternatives in a dynamic environment. A case study showed that GI-MARCOS improved the accuracy of alternatives MLR and BM by 6% and 13%, respectively. Additional validations show MLR performs best in Phase 1 and 2, ANN performs best in Phase 3 and 4, and GI-MARCOS ranks have a high correlation with GRA, COPRAS, and ARAS.
- (2023, MDPI AG): **"A Review of Data-Driven Building Energy Prediction"** This study reviews 116 research papers on data-driven building energy prediction using machine learning algorithms. It identifies outdoor dry-bulb temperature as a key factor, and suggests techniques like data preprocessing, energy consumption feature extraction, and hyperparameter optimization for prediction across time scales and building layers.
- (2023, Nature): **"Research on the community electric carbon emission prediction considering the dynamic emission coefficient of power system"** This paper discusses a community carbon emissions sample database is created using North China Power Grid emission factors. A support vector regression model is trained to forecast power carbon emissions, optimized by a genetic algorithm. A community carbon emission warning system is designed based on the results. The model fits well with both training and testing sets, achieving an 86% prediction accuracy. A specific strategy for community carbon emission reduction is proposed.
- (2023, Nature): **"Application of artificial intelligence in green building concept for energy auditing using drone technology under different environmental conditions"** This study uses drone technology to measure thermal resistances in building envelopes, a concept that has not been explored before. It considers wind speed, relative humidity, and dry bulb temperature, using drone heat mapping. The research validates the formula using artificial intelligence-based software, achieving optimal conditions of 44.90% RH, 12.61 °C DBT, and 5.20 km/h WS. The results show the drone-based technology yields consistent and effective assessment for green building development, reducing time and cost of experimentation.
- (2022, Nature): **"Short term energy consumption forecasting using neural basis expansion analysis for interpretable time series"** This paper argues that smart grids and homes are becoming increasingly important in the modern era of smart cities. However, energy efficiency and production challenges persist due to uncertainties in data and algorithm limitations. A proposed model enhances the Neural Basis Expansion Analysis for interpretable Time Series (N-BEATS) method, handling energy consumption data from thousands of customers. The model improves prediction accuracy on large datasets, including daily, weekly, and monthly predictions. It also performs better for 1-day-ahead energy consumption with "day as covariates" scenarios.
- (2022, Springer): **"Load forecasting for energy communities: a novel LSTM-XGBoost hybrid model based on smart meter data**" This paper presents a novel hybrid bi-directional LSTM-XGBoost model for energy community load forecasting that separately forecasts the general load pattern and peak loads, which are later combined to a holistic forecasting model. The hybrid model outperforms traditional energy community load forecasting based on standard load profiles as well as LSTM-based forecasts.
- (2022, MDPI AG): **"The Hourly Energy Consumption Prediction by KNN for Buildings in Community Buildings"** This paper explores the KNN algorithm, which was used to predict hourly energy consumption of community buildings using historical data. The results showed that summer and fall predictions were close to energy consumption data, while spring and winter predictions were higher. The total values of CVRMSE were within acceptable range of ASHRAE guidelines 14, indicating a consistent trend in energy consumption predictions.
- (2021, MDPI AG): **"Modeling Energy Demand—A Systematic Literature Review"** is a comprehensive study that analyzes all aspects of energy demand models, including techniques, prediction accuracy, inputs, energy carrier, sector, temporal horizon, and spatial granularity.
- (2020, IJRTE): **"Energy Performance Modelling and Consumption Forecasting in Built Environments"** This paper argues that energy consumption forecasting is crucial for future planning, especially in the construction sector, which accounts for 30% of global energy use and one-third of greenhouse gas emissions. Modeling building energy performance is crucial for policy formulation and long-term energy security. This article analyzes modeling methods, classification, and applications in constructed settings, identifying study gaps and directions for future research.

Page 12. ER10: Demand Flexibility Estimator

Software modelling the opportunity of flexibility of each asset involved in the energy community.

COMPETITORS

- **PowerShaper** is a service operated by Carbon-Coop in the UK that allows people to remotely control their electrical appliances, such as electric vehicles, battery units, solar inverters, and immersion heaters. The tool helps consumers save money and supports the flexible operation of renewable energy grids. It works by having technicians visit a consumer's home, install equipment, and use data from their smart meter to prove balancing activities. The energy community turns appliances on/off when requested by grid operators and other parties, who pay the community if they can prove the appliances were turned on/off correctly.
- **X-FLEX**, a Horizon 2020 project, developed three complementary products for energy stakeholders, including SERVIFLEX for aggregators, GRIPFLEX for grid and microgrid operators, and MARKEFLEX for energy market actors.

PAPERS

- **(2023, Springer): "Modelling renewable energy communities: assessing the impact of different configurations, technologies and types of participants**" This paper assesses the impact of different configurations, technologies, and types of participants in renewable energy communities. The authors propose a model that can be used to evaluate the impact of different configurations, technologies, and types of participants in renewable energy communities.
- **(2022, IEEE): "Smart Energy Communities Power Capacity Firming and Grid Flexibility Services**" This paper focuses on converting smart energy residential and commercial communities from variability "troublemakers" into actual providers of power firming and flexibility services. The authors propose a new approach to power capacity firming and grid flexibility services that can be implemented in smart energy communities.
- **(2022, Elsevier): "Energy-sharing mechanisms for energy community members under different asset ownership schemes and user demand profiles"** This study evaluates current and new methods for sharing renewable energy benefits among virtual net-metering energy communities. Three algorithms are proposed, distributing net profit proportionally to services provided. Six scenarios were simulated, focusing on the impact of specific sharing mechanisms on different user categories.
- **(2020, Elsevier): "A multi-agent system approach to exploit demand-side flexibility in an energy community"** This paper presents a multiagent system approach for optimizing energy communities, analyzing self-sufficiency in various scenarios, and presenting economic benefits to different community members.
- **(2020, IEEE): "A Framework to Integrate Flexibility Bids into Energy Communities to Improve Self-Consumption"** This paper introduces a framework in which demand response in the form of flexibility bids is integrated into renewable energy communities (RECs) to improve their welfare. The authors propose a new concept of RECs, composed of consumers, prosumers, and generation assets, and managed by an energy community manager.
- **(2019, IEEE): "Residential demand-side flexibility in energy communities: a combination of optimization and agent modeling approaches"** This paper combines multi-agent systems (MAS) modeling and genetic algorithms (GA) to minimize both electricity costs and end-users' dissatisfaction. The authors exploit the contribution that residential demand-side flexibility can provide to an energy community.

THESES

- **(2023, HAL): "Direct and indirect energy flexibility interactions at the building and community scale : From system to the human-interfaced system"** This thesis explores the potential synergy between human occupants and a building's energy subsystem for energy flexibility. Using the Predis-MHI platform, the study identifies EV charging as an indirect flexibility resource. The research proposes a Mixed Integer Linear Programming optimization approach, a Machine Learning-based Model Predictive Controller, and a co-simulation approach. The findings show that indirect flexibilities are essential for the energy transition and can be utilized as a primary energy flexibility resource.
- **(2022, TUD): "Flexibility in Multi Energy Systems Models and Metrics to Assess Future Energy Systems"** This thesis focuses on developing metrics for FSPs to quantify their flexibility from a portfolio of multiple P2X resources. It highlights the importance of detailed modeling and proposes model-based simulation methods for sector-coupled energy systems. The thesis also discusses the inaccuracy of existing metrics and proposes three metrics to quantify flexibility from a portfolio of flexible energy resources. The proposed metrics can encapsulate the behavior of different types of P2X resources, allowing FSPs to extract flexibility from multiple types and offer it in the market.

Page 13. **ER11: M&V Methodology**

Methodology defining the data-entry and measurement process in order to validate the energy savings and shared flexibility results.

REPORTS

- (2019, USEF): **"Developing energy flexibility in clusters of buildings: A critical analysis of barriers from planning to operation"** This paper explores building energy flexibility and its barriers and research gaps in market and policy, early planning and design, and operation. It highlights challenges in financing mechanisms, lack of appropriate tools, and socio-technical issues in the operational phase. The paper proposes targeted research directions to improve energy flexibility deployments, including capturing building demand dynamics, improving baseline estimations, and fostering seamless connectivity between buildings and districts.
- (2019, NEEP): **"Readiness for Advanced Measurement and Verification in the Northeast"** This report assesses the readiness of states and program administrators in the region to adopt advanced Metering and Vehicles (M&V) in energy efficiency programs. It identifies three indicators of readiness: regional penetration of MMI, use of advanced M&V software, and delivery of trending energy efficiency program designs. The information was gathered through web searches, correspondences, and surveys. The aim is to help utilities, evaluators, and the efficiency community share experience, understand potential opportunities, and inform future metering, M&V tools, and program designs.
- (2017, Lawrence Berkeley National Laboratory): **"The Status and Promise of Advanced M&V - An Overview of "M&V 2.0" Methods, Tools, and Applications"** This report provides a detailed overview of advanced measurement and verification (M&V) of energy efficiency savings. It discusses the techniques, differences from traditional methods, and the value propositions of M&V 2.0 to various stakeholders. The paper highlights the benefits, methods, and requirements of advanced M&V, outlines technical issues for application, and highlights the importance of tool testing, consistency, and standardization.
- (2016, MultEE): **"Identifying areas of improvements of Monitoring and Verification schemes and Coordination Mechanisms"** This report examines improvements in monitoring and verification schemes and coordination mechanisms in nine MultEE project partner countries, focusing on political governance. It is based on country reports, European best practices, and energy efficiency policies from Odyssee-Mure and the Energy Community. The countries are divided into five groups: Lithuania, Slovakia, FYR of Macedonia, Croatia, Latvia, Slovakia, Greece, Austria, Germany, and Denmark.
- (2015, MultEE): **"Synthesis report on M&V schemes and coordination mechanisms in EU countries"** This report covers the implementation status, reasons for their establishment, responsible authorities, involved parties, data sources, and legal responsibility for energy policy formulation. It also includes country fact sheets, completed and missing questionnaires, and the main conclusions of the comparative analysis.

PAPERS

- (2023, Elsevier): **"Developing energy flexibility in clusters of buildings: A critical analysis of barriers from planning to operation"** This paper explores building energy flexibility and its barriers and research gaps in market and policy, early planning and design, and operation. It highlights challenges in financing mechanisms, lack of appropriate tools, and socio-technical issues in the operational phase. The paper proposes targeted research directions to improve energy flexibility deployments, including capturing building demand dynamics, improving baseline estimations, and fostering seamless connectivity between buildings and districts.
- (2021, MDPI AG): **"DSO Flexibility Market Framework for Renewable Energy Community of Nanogrids"** This paper proposes that renewable energy communities enable the aggregation of small generation resources and users' loads, allowing for power exchange and ancillary services to the electrical system. This paper proposes a model for the interaction between DSOs and TSOs and a model for energy communities based on nanogrids.
- (2021, Elsevier): **"Flexibility options and their representation in open energy modelling tools"** This paper explores future energy systems rely heavily on variable renewable energy sources (VRES), increasing the importance of flexibility. Energy system modelling tools are used to analyze flexibility options and enhance design. However, there is no clear evaluation of how flexibility is represented in these tools. A survey was sent to developers of open energy modelling tools and analyzed using the Open ESM Flexibility Evaluation Tool (OpFEI). A combination of models through soft coupling could serve as a holistic flexibility assessment, enabling an evaluation of energy systems based on VRES.

Page 14. ER12: Open Marketplace

Blockchain-based local marketplace coupling for energy and flexibility trading, including the functionalities of intra and inter-community peer-to-peer trading with smart billing and energy certificate issuance service.

Competitors

- **(ENTRNCE Trader):** The Local4Local project, supported by Dutch government subsidies, includes ENTRNCE Trader, a tool that enables direct electricity exchange between producers and consumers in energy communities. The tool aims to increase user freedom, facilitate market transactions, and provide transparency. ENTRNCE is a scalable platform for electricity trading, offering transparent data, easy invoice preparation, and 24/7 matching for renewable production surpluses, benefiting regional organizations.
- **(Som Comunitats, Spain):** is an online platform developed by a number of Spain's energy communities, offering internal management services for their activities. It provides data visualization, project management tools, and administrative tasks. The platform is designed for citizens, public administrations, and companies in the social economy. It is managed collaboratively and transparently, with data ownership remaining with the communities. The platform is also being developed for one-stop-shops and organizations supporting energy community setup.

PAPERS

- **(2024, Elsevier):** **"Modelling the formation of peer-to-peer trading coalitions and prosumer participation incentives in transactive energy communities"** This paper is on the efficiency of peer-to-peer energy trading, highlighting benefits primarily due to diverse consumption behavior and renewable energy generation, requiring minimal contracts.
- **(2023, IEEE):** **"Blockchain Enabled Decentralized Local Electricity Markets with Negotiation-Based Auction and Pricing Mechanisms"** This paper proposes a novel blockchain-based peer-to-peer trading architecture that integrates negotiation-based auction and pricing mechanisms in local electricity markets. It automates, standardizes, and self-enforces trading procedures using smart contracts.
- **(2022, Springer):** **"Peer-to-peer energy trading optimization in energy communities using multi-agent deep reinforcement learning"** This paper presents a methodology for optimizing participation in peer-to-peer markets using a double-auction trading mechanism. It uses reinforcement learning algorithms to optimize energy transactions and prices. The methodology is competitive, aiming to minimize costs and maximize profits.
- **(2022, MDPI AG):** **"Blockchain in the Energy Sector—Systematic Review"** This paper reviews academic contributions to blockchain technology in the energy sector, focusing on practical implementations in sectors like cyber security, finance, public sector, healthcare, and industry, presenting current trends and potential research areas.
- **(2022, Springer):** **"Blockchain-Based Smart Energy Communities: Operation of Smart Legal Contract"** This paper proposes a blockchain-based open and transparent ecosystem for smart energy communities. It enables different actors to interface with each other in a natural and disintermediate way, allowing peer-to-peer trading of energy and promoting energy flexibility. The paper also presents a new dynamic smart legal contract with real data for the local marketplace within a smart energy community.
- **(2022, Frontiers):** **"A survey on peer-to-peer energy trading for local communities"** This paper investigates the energy trading enabling technologies, their applications, challenges, and benefits to the local communities from various aspects. It analyzes how blockchain and IoT technologies can help energy trading at the customer level.
- **(2021, Frontiers):** "**Application of Blockchain Technology in Energy Trading: A Review":** This paper provides a comprehensive review of the application of blockchain technology in energy trading. It discusses the potential benefits of blockchain technology, including increased efficiency, transparency, and security. The paper also examines the challenges associated with the implementation of blockchain technology in energy trading.
- **(2021, Springer):** **"Decentralised Control and Peer-To-Peer Cooperation in Smart Energy Systems"** This paper describes how decarbonised energy systems require change from electricity generation to distribution, involving communities and active control. Decentralised approaches, like decoupled microgrids and peer-to-peer networks, can empower people in the energy transition.
- **(2021, IEEE):** **"Review of Blockchain-Based Energy Trading Models"** This paper comprises an extensive review of different blockchain based energy trading model and discusses various research scopes for mitigating of certain issues with ongoing research models to gain higher efficiency.

Page 15. **ER13: Energy Gateway**

Dedicated interfaces to integrate FEDECOM (platform backend) middleware with fieldlevel devices, with bidirectional communication mechanisms.

PAPERS

- (2023, MDPI AG): **"Unlocking the Future: Fostering Human–Machine Collaboration and Driving Intelligent Automation through Industry 5.0 in Smart Cities"** This paper explores future technologies, including Industry 5.0, and their implications for smart cities. It explores various domains such as cyber-physical systems, fog computing, unmanned aerial vehicles, renewable energy, machine learning, cybersecurity, and digital forensics. The paper highlights Industry 5.0's role in enabling advanced cybersecurity measures, fostering collaboration, driving intelligent automation, and refining data management.
- (2022, MDPI AG): "**IoT Middleware Platforms for Smart Energy Systems: An Empirical Expert Survey"** This literature review and expert survey on IoT middleware platforms in energy systems, provides a set of tools and functionalities to be supported by any future efficient, flexible and interoperable IoT middleware considering the market needs.
- (2022, Springer): **"An ICT architecture for enabling ancillary services in Distributed Renewable Energy Sources based on the SGAM framework"** This paper presents a distributed ICT infrastructure for future Smart Grids, based on the Smart Grid Architecture Model (SGAM) framework. The infrastructure supports the integration of various DRESs with secure communication channels, aiding in system design analysis and verification. The proposed architecture is validated through mapping to a testbed, and further research will focus on specific-purpose use cases and the impact of connected devices on the testbed infrastructure.
- (2021, Springer): "**Web-based platform for the management of citizen energy communities and their members"** This paper proposes a platform for the management of citizen energy communities. The paper focuses and presents four services related to energy tariffs, end-users' aggregation, price elasticity, and load response. The services are based on historical data and enable deep analysis of end-users' energy profiles.

REPORTS

- (2021, Interconnect): **"Secure Interoperable IoT Smart Home/Building and Smart Energy system Reference Architecture"** This report aims to create a common vision for the InterConnect ecosystem from an architectural point of view. It defines the Secure Interoperable IoT Smart home/building and smart energy system reference architecture (SHBERA) for the technology-independent and device-agnostic InterConnect ecosystem, with four viewpoints: an energy system perspective, an IoT perspective, an IF perspective, and a SIL perspective.
- (2020, REACT): **"REACT system reference architecture"** This report outlines the architecture of the REACT platform, a cloud-based, service-oriented, and event-driven platform based on open standards. The middleware is designed with an open integration framework, the MQTT broker, for integrating information from field-level assets, EMS cloud systems, external systems, and services. An application based on OpenMUC will ensure interoperability between devices and the platform. A common messaging format, the CDM, will be defined for all devices and services. The system reference architecture includes application services and user interfaces, utilizing a microservices approach.
- (2020, SEMIoTICS): **"Field-level middleware & networking toolbox"** This report explores the integration of SDN/NFV, semantic bootstrapping, and interoperability technologies in industrial environments. It uses the SEMIoTICS architecture and Middleware to create an experimental platform with open-source software and new modules. The deliverable covers the design of SEMIoTICS field-level middleware, leveraging concepts like NFV and SDN, studying standardized semantic models, and designing a SEMIoTICS integration testbed.
- (2018, inteGRIDy): **"inteGRIDy Architecture & Functional/Technical Specifications"** This report presents the final version of the inteGRIDy Framework's architecture, including several architectural views: the Logical (Structural) View, Implementation (Development) View, Process View, Deployment (Physical) View, and Use Case View.
- (2018, PLANET): **"Definition of requirements and specifications for communication & grid interfaces"** This report focuses on the requirements for effective communication between networks and the definition of necessary interfaces throughout a system's architecture. It also discusses information flow specifications for a complete system, which will drive system architecture design, prepare a Common Information Model, and perform project standardization activities. It also discusses necessary interactions between grids and the need for protocols that span multiple grids.

Page 16. **ER14: Semantic Data Model**

Ontology enabling semantic interoperability among the relevant FEDECOM Platform modules.

REPORT

- (2019, EC): **"Ensuring interoperability for enabling Demand Side Flexibility"** This report demonstrates end-to-end semantics interoperability in the entire energy supply chain, from electricity suppliers to appliances, to maximize renewable energy use and reduce inefficiency. It highlights the need for alignment among industry standards, recommending actions for stakeholders and scaling up results for real consumer sites.

THESIS

- (2021, Polytechnic Institute of Porto): **" Ontologies for the Interoperability of Heterogeneous Multi-Agent Systems in the scope of Energy and Power Systems"** This research aims to address this by developing a society of multi-agent systems for simulation, study, decision support, operation, and intelligent management of power and energy systems. This society uses ontologies for knowledge representation and semantic web technologies for flexible adaptation to new rules and constraints.

PAPERS

- (2023, Elsevier): **"Intelligent energy systems ontology to support markets and power systems co-simulation interoperability"** This paper addresses the electricity sector's complexity and unpredictability have led to the development of software tools for simulation, study, and decision support. The Intelligent Energy Systems Ontology (IESO) addresses this by providing semantic interoperability, reasoning, constraints validation, and data uniformization within multi-agent systems.
- (2022, Elsevier): **"A semantic ontology for representing and quantifying energy flexibility of buildings"** This paper introduces EFOnt, a semantic ontology that enhances building energy flexibility applications. It aims to streamline knowledge co-development and streamline applications. EFOnt's potential use cases include energy flexibility analytics and building energy data tool ecosystem evaluation.
- (2021, MDPI AG): **"Ontologies to Enable Interoperability of Multi-Agent Electricity Markets Simulation and Decision Support"** This paper discusses the AiD-EM Ontology is a semantic representation for interoperability between multi-agent decision support systems and market agents in electricity market simulations. It addresses the gap in interoperability between heterogeneous systems, facilitating better cooperation and communication.
- (2021, Springer): **"Semantic Interoperability for Multiagent Simulation and Decision Support in Power Systems"** This work enhances interoperability between agent-based systems in electricity markets, smart grid operation, and energy management by utilizing ontologies and semantic web technologies. A multiagent systems society is presented as a proof-of-concept.
- (2021, HAL): **"SAREF-Compliant Knowledge Discovery for Semantic Energy and Grid Interoperability"** This paper discusses the importance of efficient energy management in modern cities and the integration of data from smart energy and building systems. It uses the SAREF ontology to achieve interoperability among IoT projects and devices and presents a SAREF-compliant sensor dictionary for energy scenarios.
- (2020, IDEAS): **"A Comprehensive Review of Practical Issues for Interoperability Using the Common Information Model in Smart Grids"** This paper aims to offer a comprehensive understanding by summarizing and categorizing the research on the practical use of CIM (Common Information Model) for interoperability in smart grids. Many papers are analyzed and the issues are classified into CIM extension, harmonization, and validation to address the issues that arise when establishing an integrated information exchange system.
- (2019, HAL): **"Towards semantic interoperability standards based on ontologies"** This paper, co-authored by experts in IoT standards, aims to explain semantic interoperability and provide recommendations for standards using ontologies. It targets IoT system product owners and engineers without semantic technology background.
- (2019, IEEE): **"Multi-agent semantic interoperability in complex energy systems simulation and decision support"** This work introduces a multi-agent systems society for simulation and decision support, using a semantic data model for communication and interoperability. A semantic registration and search platform facilitates interoperability. Advanced AI-based decision support models enhance outcomes. An integrated simulation and emulation infrastructure is presented for realistic testing and validation.
- (2017, Springer): **"Semantic Knowledge and Service Models for Energy-Aware Systems"** This research shows how energy-related information and concepts, from weather and energy market information to sensor data, are semantically described and how services using the semantic information can manifest themselves in the same semantic way to be used in a network of energy awareness-related services.

Page 17. ER15: Visualisation Tools

User-specific graphical interfaces for visualisation of relevant operation and performance data.

REPORTS

- (2021, ESB): **"Data Platforms and Dashboards"** This report outlines Piclo, a Market Flexibility Services platform being used in Ireland, which enables energy communities to engage in grid services bidding, register assets online, and monitor local energy systems through dashboards.
- (2020, Amsterdam University Press): **"Data Visualization in Society"** This report explores data visualization's political significance, social media analytics, accessibility, evaluation, and inequalities. It also explores data visualization literacy, semiotics, aesthetics, and journalism application, providing a comprehensive resource.

PAPERS

- (2023, MDPI AG): **"Integration with Visual Perception—Research on the Usability of a Data Visualization Interface Layout in Zero-Carbon Parks Based on Eye-Tracking Technology"** This study used eye-tracking technology to analyze data readability of six types of carbon emission visualization interfaces in parks.
- (2022, MDPI AG): **"Building Energy Simulation and Monitoring: A Review of Graphical Data Representation"** This paper is a review of the state-of-the-art of visualization techniques used in the field of energy performance, in particular by considering two types of building analysis: simulation and monitoring. Data visualizations are categorized according to goals, level of detail, and target users.
- (2022, Springer): **"Towards more effective visualisations in climate services: good practices and recommendations"** This paper summarises a workshop on visualisation challenges by climate service providers outlines good practices from other disciplines, including user experience, data visualization, graphic design, and psychology.

COMPETITORS

- (US DOE): **"Coal Power Plant Redevelopment Visualization Tool"** is an open access tool developed by Interagency Working Group on Coal & Power Plant Communities & Economic Revitalization, is powered by the U.S. Department of Energy's National Energy Technology Lab. It is a public database and map that aids economic development officials, project developers, and power plant owners in identifying potential redevelopment opportunities.
- (AEGIS IT): **"Advanced Visualisation Toolkit - Energy Community Demo (video)"** This study aims to identify unfair energy consumption patterns among Energy Community members using historic smart-meter data. A synthetic dataset from 2020 shows Consumer2 consumes significantly more energy than other members due to charging needs for an EV. This data can help adjust maintenance costs accordingly.
- EnergyID **is a monitoring tool that collects, analyzes, and compares energy, water, waste, and transport** data for individual and collective consumption. It processes data into graphs, allows quick comparisons, and integrates with PV inverters and smart metering systems. Users can share data with communities and receive premium features like measurement verification and custom dashboards.

NEWS

- (2024, Toptal): **"A Complete Overview of the Best Data Visualization Tools"** This blog post provides a comprehensive overview of top data visualization tools, including Tableau, Infogram, ChartBlocks, Datawrapper, D3.js, Google Charts, FusionCharts, Chart.js, Grafana, Chartist.js, Sigmajs, and Polymaps, highlighting their features, pros, cons, and the importance of project needs and learning curves.
- (2023, Utilities One): **"The Role of Data Visualization in Smart Grid Decision-Making"** This webpage describes how data visualization is crucial in smart grid decision-making, transforming complex data into meaningful insights, improving situational awareness, and engaging stakeholders.
- (2023, Heavy.AI): **"Interactive Data Visualization Definition"** Interactive data visualization is a software that allows users to manipulate and explore graphical representations of data using techniques like brushing, painting, identification, scaling, and linking.
- (2023, Radar): **"Exploring 12 of the Best Data Visualization Tools in 2023 With Examples"** This news item provides a thorough overview of data visualization tools, including their significance in data science, factors to consider, and top open-source Python, R, and GUI-based options. It covers features, pros, and cons of each tool.
- (2023, Real Python): **"Develop Data Visualization Interfaces in Python with Dash"** This tutorial provides a comprehensive guide on creating data visualization interfaces in Python using Dash, a framework that enables data scientists to build analytical web applications using pure Python, covering setting up, building, layout, and styling.

Page 18. In the 'energy community' news (1)

Page 18 is the first of three pages on the general topic of energy communities, including: 4 reports and 7 scientific papers.

REPORTS

- (2023, Sun4All): **"The EU framework on energy communities"** This policy brief highlights the political and regulatory context for energy communities, highlighting their social role and the need for increased support.
- (2023, JRC): **"MODECO – Modelling study on the role of energy communities in the energy transition"** The report examines the impact of external factors on the operational and investment decisions of five Energy Community typologies in Germany and Spain. Four different schemes were tested: No Charges, Time-of-Use (TOU), Subscription Bandwidth, and Peak power. The study found that none of the evaluated tariff structures pose significant barriers to future expansion, and power-based charges like Bandwidth and Peak power can avoid overinvestment in batteries.
- (2021, IRENA): **"Community Energy Toolkit: Best practices for broadening the ownership of renewables"** This report provides best practices for community energy, focusing on active participation and ownership by citizens in renewable energy projects. The toolkit includes 11 case studies and an analytical framework, identifying seven dimensions for community energy initiatives, including ownership, governance, location, technology, financing, socio-economic impacts, cultural considerations, and gender.
- (2020, JRC): **"Energy communities: an overview of energy and social innovation"** This reprt discusses the drivers, societal benefits of energy communities, and their contributions to renewables expansion. It also analyses the implications of energy communities as new actors for consumers and the energy system. The analysis draws evidence from literature review and 24 case studies of community energy projects.

PAPERS

- (2023, MDPI AG): **"Key Aspects and Challenges in the Implementation of Energy Communities"** This paper examines the regulatory framework, established energy communities, key technologies, and data management challenges for energy community implementation. It highlights the need to address regulatory compliance with the legal framework, data management when adopting innovative technologies, and financing for new projects to ensure the successful implementation of the energy community concept. The paper also provides an overview of financing schemes to support energy community development.
- (2023, NEON): **"A review of Energy Communities: Definitions, Technologies, Data Management"** This paper aims to give an overview of the most important aspects for the success of the energy community (EC) concept and provides the needed literature resources for new entrants into the field of ECs.
- (2022, Open Research Europe): **"European small-town Renewable Energy Communities: Participatory design of supporting tools as a vehicle to engage and understand local communities and their energy related concerns"** This paper discusses the participatory design of supporting tools as a vehicle to engage and understand local communities and their energy-related concerns.
- (2022, MDPI AG): **"Energy Communities Overview: Managerial Policies, Economic Aspects, Technologies, and Models"** This study examines the role of energy communities (ECs) in modern energy management, focusing on their role in ensuring energy safety, autonomy, and alleviation. It organized ECs into four groups: technology and environment, socio-culture and anthropocentricity, legislative dimensions, and EU-ECs. Key literature aspects, proposed measures, and energy policies were also discussed.
- (2022, IEEE): **"Methods and Tools for the Management of Renewable Energy Communities: the ComER project"** This paper is based on the ComER project, developed by the University of Cassino and Campus Bio-Medico University of Rome, aims to develop methods and tools for managing and controlling RECs. The project focuses on technical problems, Italian legislation rules, project organization, adopted solutions, and initial results.
- (2022, EnergyCon / IEEE): **"Operation Orchestration of Local Energy Communities through Digital Twin: A Review on suitable Modeling and Simulation Approaches**" This paper outlines the requirements for developing (digital twins) DT for local energy community (LEC) operation orchestration, focusing on physics-based and data-driven models. It discusses the flexibility profile of LEC based on data-driven models for balancing reserves.
- (2021, Springer): **"The current state of research on energy communities"** This paper classifies energy communities, analyzing terminology, components, and structure. Space-saving components, like PV and storage, are most used, with aggregators making formation easier for non-engineers.

Page 19. **In the 'energy community' news (2)**

Page 19 continues on the general topic of energy communities, including 14 news items.

NEWS

- (2024, Clean Technica): **"The National Community Solar Partnership Summit"** will be free and fully virtual on 14 February from 12:00–4:00 p.m. ET. The theme will be "Community Solar – Deploying Benefits & Delivering Impacts".
- (2024, PR Newswire): **"Arcadia becomes first community solar provider to reach 2GW capacity"** Arcadia, a technology company, has become the first community solar provider to reach 2 gigawatts of capacity, making it the largest manager of community solar projects in the US.
- (2024, LEXOLOGY): **"Greek electricity update 2023"** From now on, energy communities in Greece will be formed as Renewable Energy Communities (RECs) or Citizen Energy Communities, while those established in compliance with Law 4513/2018 may be transformed into the new forms.
- (2024, Tech Xplore): **"Fairly sharing the pains and the gains of energy systems"** discusses the inequalities in energy systems, highlighting two key injustices: unequal access to energy systems and disparities in the negative consequences they bring. The focus is on a need for fair distribution of benefits and burdens in energy communities.
- (2024, Solar power world): **"Federal and local support grows for solar in low- and moderate-income (LMI) communities"** The article highlights the growing support for solar energy in low- and moderate-income (LMI) communities, emphasizing the need for equitable solar siting and the role of federal and local incentives.
- (2024, Utility Dive): **Utilities' misguided opposition to community solar in California"** This article discusses the opposition of California's three largest utilities to an equitable community solar program by the Public Utilities Commission, despite its potential benefits for renters and disadvantaged communities.
- (2024, DW): **"How a German town wants to reinvent clean energy sharing"** This article discusses Bürgerenergie Rhein-Sieg, a citizen energy cooperative in Siegburg, Germany, aiming to promote energy sharing through a solar park. However, it highlights obstacles like lack of favorable treatment and high costs.
- (2024, DW): **"Bulgaria - Pioneering grassroots energy project bears fruit"** Bulgaria is lagging Europe in clean energy production, but a democratic energy movement led by Izgrei, initiated by two brothers in Belozem, is addressing energy poverty and promoting clean energy. The grassroots initiative, which started with nine panels and four co-owners, embodies larger citizen-energy communities in northern Europe.
- (2024, Street Insider): **"Hyperfuel Labs Launches the World's First Industrial-Scale Testbed and Accelerator for Hydrogen Startups"** Hyperfuel Labs, a MIT-alumnus-founded venture, has established the world's first industrial-scale testbed and accelerator for hydrogen startups, aiming to accelerate clean hydrogen technologies and achieve net-zero emissions by 2050. They also have plans to foster the next-generation hydrogen workforce development through training and apprenticeship programs for underprivileged and legacy energy communities.
- (2024, Solar Builder): **"IRA offers lucrative incentives for low-income community solar, but also creates new challenges"** The Inflation Reduction Act (IRA) provides tax credits and direct payment for low-income community solar projects, boosting development. However, challenges include qualifying households, raising awareness, and navigating complex documentation. The IRA could significantly impact state programs and market behavior.
- (2024, NREL): **"American-Made Prize Accelerates Community Solar Initiatives Across the US"** The American-Made Prize, a $10 million competition, aims to support new solar developers and co-developers.
- (2024, CERTs): **"2024 CERTs Seed Grants awarded to 45 community-based clean energy projects"** The Clean Energy Resource Teams awarded seed grants to 45 Minnesota community-based clean energy projects in 2024, aiming to support historically underserved communities with high energy burdens.
- (2024, The Mirage): **"Fairly sharing pains and gains of energy systems"** This article highlights the importance of addressing injustices in energy systems, particularly within energy communities, to achieve fair access and distribution. It calls for focused action, collaboration, and public awareness to address these issues.
- (2024, The Energy Mix): **Battery Storage Firms See Promise in California's Community Solar Market"** California's community solar program is focusing on battery storage to support clean energy infrastructure. The CPUC is finalizing guidelines for the program, with a deadline of July. The Net Value Billing Tariff (NVBT) proposal aims to enhance grid reliability, simplify billing options, and lower barriers for low-income subscribers.

Page 20. In the 'energy community' news (3)

Page 19 continues on the general topic of energy communities, including 14 news items.

NEWS (continued)

- (2024, Tech Xplore): **"Trading between households in smart energy communities"** This article discusses the rise of energy communities, reducing dependency on large suppliers and alleviating grid congestion. A study using UK real data and AI techniques explores the formation of trading coalitions and prosumer participation incentives in transactive energy communities, finding diminishing returns.
- (2024, EurekAlert): **"Trading between households in smart energy communities: the more the merrier?"** This article is about a study published in Applied Energy explores the formation of peer-to-peer trading coalitions and prosumer participation incentives in transactive energy communities. The research, a collaboration between various institutions, uses large-scale real data from the UK to analyze marginal benefits of peer-to-peer energy exchange contracts and the impact of increasing contracts on consumption diversity.
- (2024, PV Magazine): **"Seven community solar projects to deliver bill savings to low-income residents"** Seven community solar projects in Illinois and New York aim to help 5,000 low- to moderate-income households, public schools, and private organizations reduce retail electricity costs by 20% and avert 667,788 metric tons of CO2 emissions, with total customer savings exceeding $17 million over their lifespan.
- (2024, CMS LAW NOW): **"Multiple participation in Energy Communities from 2024"** In Austria, the Electricity Industry and Organisation Act now permits multiple participation in energy communities, enhancing flexibility in energy generation and fostering diverse participation levels. By April, this will enable consumers and producers to engage in multiple renewable energy communities, benefiting the real estate sector for site selection and project marketing.
- (2024, PV Magazine): **"Colombia introduces new provisions for energy communities"** Colombia's Ministry of Mines and Energy has introduced new regulations for energy communities, allowing collective self-generation and distributed generation. The regulations also allow associations and a maximum power limit for self-consumption.
- (2024, Nonprofit Quarterly): **Puerto Rican Advocates Pursue Community Control of Renewable Energy"** Hurricane Maria exposed vulnerabilities in Puerto Rico's centralized power grid, prompting community-driven renewable energy push. Government aims for 100% renewable power by 2050, but challenges persist. Solutions include empowering community groups, improving distribution, and promoting transparency and community involvement.
- (2024, Balkan green energy news): **"Slovenia gets first energy cooperative self-supply solar power system"** The Zeleni Hrastnik energy cooperative in Slovenia has installed the first photovoltaic system for joint self-supply, generating electricity for 16 apartments, a swimming pool, a small business space, and two private firms.
- (2024, Business News Wales): **"Community Energy Report Highlights Opportunities as Wales Ends Dependence on Fossil Fuels"** Community Energy Wales' report highlights Wales' potential for community energy, including cost savings, long-term income, and green jobs. However, barriers like funding and grid backlogs hinder expansion.
- (2023, PV Magazine): **"Denmark supports first energy communities"** The Danish Energy Agency says it dished out a total of DKK 4.2 million ($61,9542) in grant funding this year to nine local energy communities and projects supporting renewable energy. Projects include an energy community start-up guide for rural environmentalists to an energy community feasibility study in a decades-old garden association.
- (2023, PV Magazine): **"France expands limits of energy communities"** The French government issued a long-awaited decree to expand the maximum permitted distance between members of energy communities from 2 km to 20 km.
- (2023, PV Magazine): **"Dynamic allocations increase financial savings in energy communities"** A global research group has compared static, customized dynamic, and dynamic-by-default energy allocations at a collective self-consumption project in France. They have found that dynamic customization performs better due to tax benefits.
- (2023, Energy Post): **"EU now has 9,000+ "energy communities"** which contribute to decentralization, smartness, and flexibility, particularly in renewable energy generation.
- (2023, NYSERDA): **"Clean Energy Communities Program Helps Reduce Energy Use, Lower Costs and Offers Additional Support for Projects Located in Disadvantaged Communities"** New York Governor Kathy Hochul has announced $25 million in funding for the Clean Energy Communities Program, which assists local municipalities in implementing high-impact clean energy actions and reducing greenhouse gas emissions. The program, administered by NYSERDA, offers grants for clean energy projects, and provides guidance for municipalities.
- (2022, JRC): **"Magliano Alpi: a peek at the energy communities of the future (video interview)"** This webpage highlights Italy's first renewable energy community in Magliano Alpi. It also mentions the Erigrid 2.0 project's tool for energy communities to match their energy needs with their production potential. The tool forecasts aggregate energy needs and self-consumption volumes, considering seasonal trends and geographical spread.