Energy Informatics.Academy Conference 2022

Technical program

SDU CENTER FOR ENERGY INFORMATICS

Springer Open

SDC The university partnership Denmark – China

Energy Informatics.Academy The global community for energy informatics

European Union European Social Fund

IICE

Table of Content

Preface

The Energy Informatics.Academy Conference 2022 (EI.A 2022) has collected great contributions from researchers and practitioners in various scientific, technological, engineering and social fields to disseminate original research on the application of digital technology and information management theory and practice to facilitate the global transition towards sustainable and resilient energy systems.

With the whole technical program committee's effort, in total thirty-two (32) high-quality papers (including full papers and short papers) are accepted and will be presented at the conference.

Sincerely,

General Chairs

Bo Nørregaard Jørgensen, University of Southern Denmark, Denmark
Guangchao Chen, University of Chinese academy of sciences, China
Birte Holst Jørgensen, Technical University of Denmark, Denmark

Program Committee Chair

Zheng Grace Ma, University of Southern Denmark, Denmark

Technical Program Committee Chairs

Henrik Madsen, Technical University of Denmark, Denmark
Luiz Carlos Pereira da Silva, University of Campinas (Unicamp), Brazil
Hongbo Duan, University of Chinese academy of sciences, China

Thanks again to the Technical Program Committee of

Name	Affiliation	Country
Zita Vale	Engineering institute - Polytechnicof Porto	Portugal
Zhilin Huang	Huaqiao University	China
Yun Lin	Harbin Engineering University	China
Xu Yan	Nanyang Technological University	Singapore
Xiufeng Liu	Technical University of Denmark	Denmark
Wesley Angelino de Souza	Federal University of Technology Paraná	Brazil
Wanyang Dai	Nanjing University	China
Wahidah Binti Hashim	Universiti Tenaga Nasional	Malaysia
Sisil Kumarawadu	University of Moratuwa	Sri Lanka
Sebastian Büttrich	IT-University of Copenhagen	Denmark
Salman Yussof	Universiti Tenaga Nasional	Malaysia
Roberto Perillo Barbosa da Silva	Federal University of Mato Grosso	Brazil
Ricardo Fernandes	Federal University of São Carlos	Brazil
Qian Ai	Shanghai Jiao Tong University	China
Pierluigi Siano	University of Salerno	Italy
Phuong Nguyen	Eindhoven University of Technology	Netherlands
Pedro P. Vergara	Delft University of Technology	Netherlands
Nicolas Fatras	University of Southern Denmark	Denmark
Marini Othman	INTI International University	Malaysia
Li Xia	Sun Yat-Sen University	China
K. Shanti Swarup	Indian Institute of Technology	India
Jong Bae Park	Konkuk University	South Korea
Jonathan Dallaire	University of Southern Denmark	Denmark
Jayaprakash Rajasekharan	Norwegian University of Science and Technology	Norway
Irene Chew	Monash University	Australia
Iker Esnaola-Gonzalez	Tekniker	Spain
Hazleen Binti Aris	Universiti Tenaga Nasional	Malaysia
Hamid Reza Shaker	University of Southern Denmark	Denmark
Hamdi Ben Hamadou	Aalborg University	Denmark
Fernando Pinhabel Marafão	São Paulo State University	Brazil
Fabio Lilliu	Aalborg University	Denmark
Enrique Kremers	European Institute for Energy Research	Germany
Daisuke Mashima	University of Illionois	Singapore
Chiara Bordin	UiT The Arctic University of Norway	Norway
Chau Yuen	Singapore University of Technology and Design	Singapore
Azizah Suliman	Universiti Tenaga Nasional	Malaysia
Athila Quaresma Santos	University of Southern Denmark	Denmark
Ankur Singh Bist	Graphic Era Hill University Bhimtal Campus	India
An Liang	The Hong Kong polytechnic university	China
Amir Laadhar	Aalborg University	Denmark

Program

Day one conference program (24 August 2022)

Overview

Physical location: Green Tech House, Dandy business park (Lysholt Allé 6, 7100 Vejle, Denmark; see the map in the **Practical information section**)
Room: Solcellen & Ladestationen; Zoom meeting link: https://syddanskuni.zoom.us/j/67756421308
Room: Solbrønden; Zoom meeting link: https://syddanskuni.zoom.us/j/64925455039

Time (CET)	Activity		Room	Zoom link
8.30-15.00	**Registration**			
9.00-9.20	Conference opening: Welcome by Prof. Bo Nørregaard Jørgensen, EI.A conference 2022 committee chair and head of SDU Center for Energy Informatics		Solcellen & Ladestationen	Zoom meeting link
	Conference opening: Welcome by Morten Laugesen, Executive Director of Sino-Danish Centre			
9.20-10.20	Paper presentation session	Theme of Simulation and modeling in energy	Solcellen & Ladestationen	Zoom meeting link
	Paper presentation session	Theme of Software and applications in energy	Solbrønden	Zoom meeting link
10.20-10.30	Coffee break			
10.30-12.00	Paper presentation session	Theme of Simulation and modeling in energy	Solcellen & Ladestationen	Zoom meeting link
	Paper presentation session	Theme of Software and applications in energy	Solbrønden	Zoom meeting link
12.00-13.00	Lunch break			
13.00-14.10	Paper presentation session	Theme of Big data and AI in energy	Solcellen & Ladestationen	Zoom meeting link
	Paper presentation session	Theme of Energy informatics projects and analysis	Solbrønden	Zoom meeting link
14.10-14.20	Coffee break			
14.20-16.00	Paper presentation session	Theme of Big data and AI in energy	Solcellen & Ladestationen	Zoom meeting link
	Paper presentation session	Theme of Energy informatics projects and analysis	Solbrønden	Zoom meeting link
16.00-17.00	Technic tour at Dandy business park	Jørgen Andersen, CEO of DANDY Business Park	Solcellen & Ladestationen	Zoom meeting link
19.00-22.00	Formal dinner	BEST WESTERN ToRVEhallerne (Address: Fiskergade 2-8, DK-7100 Vejle)		

Morning paper presentation session: Simulation and modeling in energy

Room: Solcellen & Ladestationen; Zoom meeting link: https://syddanskuni.zoom.us/j/67756421308

Time (CET)	Presenter	Title
9.20-9.40	Pietro rando Mazzarino	A Comparison Study of Co-simulation Frameworks for Multi-Energy Systems: The Scalability Problem
9.40-10.00	Petrit Vuthi	Agent-based modeling (ABM) for urban neighborhood energy systems: Literature review and proposal for an all integrative ABM approach
10.00-10.20	Nicolas Fatras	An agent-based modelling framework for the simulation of large-scale consumer participation in electricity market ecosystems
10.20-10.30	Coffee break	
10.30-10.50	Athila Q. Santos	Framework for Dimensioning Battery Energy Storage Systems with Applied Multi-tasking Strategies in Microgrids
10.50-11.10	Reinhard German	Simulation of a Cellular Energy System including Hierarchies and Neighborhoods
11.10-11.30	Claudia De Vizia	A Hierarchical and Modular Agent-Oriented Framework for Power Systems Co-Simulations
11.30-11.50	Malte Chlosta	An Adapter-Based Architecture for Evaluating Candidate Solutions in Energy System Scheduling
11.50-12.05	Henrik Alexander Nissen Søndergaard	Automatic Process Monitoring in a District Heating Substation Utilizing a Contextual Shewhart Chart

Morning paper presentation session: Software and applications in energy

Room: Solbrønden; Zoom meeting link: https://syddanskuni.zoom.us/j/64925455039

Time (CET)	Presenter	Title
9.20-9.40	Md Anam Raihan	SGLSim: Tool for Smart Glazing Energy Performance Analysis
9.40-10.00	Gabriel Santos	Open-access Tools for the Modelling and Simulation of Electricity Markets
10.00-10.20	Marco Castangia	Non-Intrusive Load Monitoring techniques for the disaggregation of ON/OFF appliances
10.20-10.30	Coffee break	
10.30-10.45	Pedro Baptista	Design of Data Management Service Platform for Intelligent Electric Vehicle Charging Controller - Multi-charger Model
10.45-11.00	Shari Alt	Design of an intelligent trading platform for flexibility potentials of private households in the low-voltage grid
11.00-11.20	Christian Skafte Beck Clausen	Can we benefit from game engines to develop digital twins for planning the deployment of photovoltaics?
11.20-11.40	Hessam Golmohamadi	Probabilistic FlexOffers in Residential Heat Pumps Considering Uncertain Weather Forecast
11.40-12.00	Jonas Vedsted Sørensen	Potentials of game engines for wind power digital twin development: an investigation of the Unreal engine

Afternoon paper presentation session: Big data and AI in energy

Room: Solcellen & Ladestationen; Zoom meeting link: https://syddanskuni.zoom.us/j/67756421308

Time (CET)	Presenter	Title
13.00-13.20	Helder Pereira	Peer-to-Peer Energy Trading Optimization in Energy Communities using Multi-Agent Deep Reinforcement Learning
13.20-13.40	Pavan Ramapragada	Investigation on Air Conditioning Load Patterns and Electricity Consumption of Typical Residential Buildings in Tropical Wet and Dry Climate in India
13.40-13.55	Dharani Tejaswini K	Residential Electricity current and appliance dataset for AC-event detection from Indian Dwellings
13.55-14.10	Nur Shakirah Md Salleh	An implementation of long short-term memory on electricity load forecasting: comparison of multiple scalers
14.10-14.20	Coffee break	
14.20-14.40	Marco Petri	Anomaly detection in quasi-periodic energy consumption data series: a comparison of algorithms
14.40-15.00	Sebastian Pütz	Revealing interactions between HVDC cross-area flows and frequency stability with explainable AI
15.00-15.20	Surya Venkatesh Pandiyan	Recursive training based Physics Inspired Neural Network for Electric Water Heater modeling
15.20-15.40	Nicolai Bo Vanting	Evaluation of Neural Networks for Residential Load Forecasting and the Impact of Systematic Feature Identification
15.40-16.00	Simon Hedegård Jessen	Identification of natural disaster impacted electricity load profiles with k means clustering algorithm

Afternoon paper presentation session: Energy informatics projects and analysis

Room: Solbrønden; Zoom meeting link: https://syddanskuni.zoom.us/j/64925455039

Time (CET)	Presenter	Title
13.20-13.40	Abbas M. Al-Ghaili	Can electric vehicles be an alternative for traditional fossil-fuel cars with the help of renewable energy sources towards energy sustainability achievement?
13.40-14.00	Kuntal Chattopadhyay	Impact of the COVID-19 on residential energy consumption of Hyderabad, India.
14.00-14.15	Lasse Mortensen	A probabilistic approach to reliability analysis of district heating networks incorporation censoring: A report of implementation experiences
14.15-14.25	Coffee break	
14.25-15.45	Daniel Howard	Application of Energy Informatics in Danish Research Projects
14.45-15.05	Kristoffer Christensen	Ecosystem-driven business opportunity identification method and web-based tool with a case study of the electric vehicle home charging energy ecosystem in Denmark
15.05-15.20	Zheng Grace Ma	Survey data on university students' experience of energy control, indoor comfort, and energy flexibility in campus buildings
15.20-15.35	Bo Nørregaard Jørgensen	CELSIUS: an international project providing integrated, systematic, Cost-effective large-scale IoT solutions for improving energy efficiency of medium- and large-sized buildings

Day Two conference program (25 August 2022)

Physical location: Tent No.7, Green Zone of the Innovation Festival, Dandy business park (Address: Lysholt Allé 1-10, 7100 Vejle, Denmark; please see the map in the **Practical information section**)
Zoom meeting link: https://syddanskuni.zoom.us/j/64002255125

Time	Theme	Speakers
9.00-9.45	Morning coffee and co-event Innovation Festival welcome	
10.00-10.20	EI.A conference Day 2 opening	
10.20-10.50	Keynote speech-Digital Twin Modelling of Energy Systems	Bo Nørregaard Jørgensen, Professor, founder and head of SDU Center for Energy Informatics at the University of Southern Denmark
10.50-11.20	Keynote speech-Data-Driven Methods for Smart Energy Systems	Henrik Madsen, Section head and professor in Stochastic Dynamical Systems at the Technical University of Denmark
11.20-11.30	Coffee break	
11.30-12.00	Keynote speech- FlexOffers: Towards an Open Standard for Energy Flexibility	Torben Bach Pedersen, Professor of computer science at Aalborg University and co-founder of FlexShape
12.00-12.30	Keynote speech-Data-driven innovation for the green transition	Søren Skov Bording, CEO Center Denmark and Business Development Engineer
12.30-13.30	Lunch break	
13.30-14.00	Keynote speech-The importance of digitization and architectural thinking to drive long term sustainability	Brian Skov Lykke Rasmussen, Managing Director of IBM Denmark
14.00-15.00	Panel session-Accelerating the digital transformation in energy systems	Brian Skov Lykke Rasmussen Bo Nørregaard Jørgensen Torben Bach Pedersen Henrik Madsen Søren Skov Bording
15.00-15.15	Coffee break	
15.15-16.00	Conference closing and next year conference announcement	
16.00-16.30	Co-event Innovation Festival closing	

Keynote speakers

The importance of digitization and architectural thinking to drive long term sustainability

Brian Skov Lykke Rasmussen
Managing Director, IBM

Brian Skov Lykke Rasmussen is passionate about applying technology to transform businesses and society. Brian has led several transformation projects during his 25 years IT career - ranging from IT infrastructure to organizations, processes, and compliance. Throughout his career, he has been engaged in designing and implementing critical IT infrastructure and applications on behalf of the largest and most influential companies in Denmark and the Nordics. Latest, in the capacity of CTO for IBM in the Nordics, he played a key role in aligning IBM's technical community in the Nordics to IBM's new strategy. Today, Brian is Managing Director for IBM's business with Danske Bank, where IBM's technology and people play a significant role. Outside IBM, besides mentoring and coaching many technical talents inside and outside IBM, Brian is a member of the Digital Wisemen Council in Denmark where he is focused on Sustainable Digitization.

Digital Twin modelling of Energy Systems

Prof. Bo Nørregaard Jørgensen
Founder and head of Center for Energy Informatics at the University of Southern Denmark

Professor, Dr. Bo Nørregaard Jørgensen is the founder and head of the Center for Energy Informatics at the University of Southern Denmark. Center for Energy Informatics is an interdisciplinary research center focusing on digital solutions for facilitating the transition toward a sustainable energy system. The center's research is conducted in close collaboration with industrial partners, public bodies, and government agencies. Dr. Jørgensen research focuses on digital solutions for integration of the demand-side with the supply-side in the energy sector, from the technology and business perspectives. He holds a Ph.D. in Computer Science from the University of Southern Denmark, a M.Sc. and a B.Sc. in Computer System Engineering from Odense University, Denmark.

Keynote speakers

Data-driven methods for Smart Energy Systems

Prof. Henrik Madsen
Section head in Stochastic Dynamical Systems, Technical University of Denmark

He got a PhD in Statistics at the Technical University of Denmark in 1986. He was appointed Ass. Prof. in Statistics in 1986, Assoc. Prof. in 1989, and Professor in Mathematical Statistics with a special focus on Stochastic Dynamical Systems in 1999. In 2017 he was appointed Professor II at NTNU in Trondheim. His main research interest is related to analysis and modelling of stochastic dynamics systems. This includes signal processing, time series analysis, identification, estimation, grey-box modelling, prediction, optimization and control. The applications are mostly related to Energy Systems, Informatics, Environmental Systems, Bioinformatics, Biostatistics, Process Modelling and Finance. He has got several awards. Lately, in June 2016, he has been appointed Knight of the Order of Dannebrog by Her Majesty the Queen of Denmark, and he was appointed Doctor HC at Lund University in June 2017. He has authored or co-authored approximately 650 papers and 12 books. The most recent books are Time Series Analysis (2008); General and Generalized Linear Models (2011); Integrating Renewables in Electricity Markets (2013), and Statistics for Finance (2015).

FlexOffers: Towards an Open Standard for Energy Flexibility

Prof. Torben Bach Pedersen
Co-founder of FlexShape, Professor of computer science, Aalborg University

Torben Bach Pedersen is a professor of computer science at Aalborg University, Denmark and co-founder of FlexShape, focusing on Big Data Analytics with applications in Digital Energy. He has published more than 320 peer-reviewed papers which received more than 7700 citations on Google Scholar, yielding an h-index of 49. He serves on the PCs of the top conferences in (big) data management (SIGMOD, PVLDB, ICDE, CIKM, and EDBT) and digital energy (ACM e-Energy). He is an ACM Distinguished Scientist, an IEEE Distinguished Contributor, and a Member of the Danish Academy of Technical Sciences. He received the Best Paper Award at ACM e-Energy and an Honorary Doctorate from TU Dresden for his work on managing energy flexibility using FlexOffers, which are used in more than 20 EU and national research projects with thousands of prosumers, and a number of commercial products. He is a co-founder of FlexCommunity.eu, the European forum for energy flexibility.

Keynote speakers

Data-driven innovation for the green transition

Søren Skov Bording
CEO Center Denmark and Business Development Engineer

Søren Skov Bording is passionate about transforming new science and technologies into new businesses and has many years of experience building new digital business models within the energy sector for the benefit of the green transition. Søren Skov Bording has established the car sharing company TADAA! that solely use electric vehicles and as director of Load and Control organization in Vestas, he has experience leading a large global organization within digital technologies in the very core of developing new turbine variants. He is now using his experience from the production side of the energy system to improve data driven solutions on the consumption side.

Paper themes

Theme	Paper title
Simulation and modeling in energy	A Comparison Study of Co-simulation Frameworks for Multi-Energy Systems: The Scalability Problem Agent-based modeling (ABM) for urban neighborhood energy systems: Literature review and proposal for an all integrative ABM approach An agent-based modelling framework for the simulation of large-scale consumer participation in electricity market ecosystems Framework for Dimensioning Battery Energy Storage Systems with Applied Multi-tasking Strategies in Microgrids Simulation of a Cellular Energy System including Hierarchies and Neighborhoods A Hierarchical and Modular Agent-Oriented Framework for Power Systems Co-Simulations An Adapter-Based Architecture for Evaluating Candidate Solutions in Energy System Scheduling Automatic Process Monitoring in a District Heating Substation Utilizing a Contextual Shewhart Chart
Software and applications in energy	SGLSim: Tool for Smart Glazing Energy Performance Analysis Open-access Tools for the Modelling and Simulation of Electricity Markets Non-Intrusive Load Monitoring techniques for the disaggregation of ON/OFF appliances Design of Data Management Service Platform for Intelligent Electric Vehicle Charging Controller - Multi-charger Model Design of an intelligent trading platform for flexibility potentials of private households in the low-voltage grid Can we benefit from game engines to develop digital twins for planning the deployment of photovoltaics? Probabilistic FlexOffers in Residential Heat Pumps Considering Uncertain Weather Forecast Potentials of game engines for wind power digital twin development: an investigation of the Unreal engine

Paper themes

Theme	Paper title
Big data and AI in energy	Peer-to-Peer Energy Trading Optimization in Energy Communities using Multi-Agent Deep Reinforcement Learning Investigation on Air Conditioning Load Patterns and Electricity Consumption of Typical Residential Buildings in Tropical Wet and Dry Climate in India Residential Electricity current and appliance dataset for AC-event detection from Indian Dwellings An Implementation of Long Short-Term Memory on Electricity Load Forecasting: Comparison of Multiple Scalers Anomaly detection in quasi-periodic energy consumption data series: a comparison of algorithms Revealing interactions between HVDC cross-area flows and frequency stability with explainable AI Recursive training based Physics Inspired Neural Network for Electric Water Heater modeling Evaluation of Neural Networks for Residential Load Forecasting and the Impact of Systematic Feature Identification Identification of natural disaster impacted electricity load profiles with k means clustering algorithm
Energy informatics projects and analysis	The increasing cooling and electricity demand under climate change Can electric vehicles be an alternative for traditional fossil-fuel cars with the help of renewable energy sources towards energy sustainability achievement? Impact of the COVID-19 on residential energy consumption of Hyderabad, India. A probabilistic approach to reliability analysis of district heating networks incorporation censoring: A report of implementation experiences Application of Energy Informatics in Danish Research Projects CSTEP-driven business opportunity identification method with a case study of energy use in industrial processes Survey data on university students' experience of energy control, indoor comfort, and energy flexibility in campus buildings CELSIUS: an international project providing integrated, systematic, Cost-effective large-scale IoT solutions for improving energy efficiency of medium- and large-sized buildings

Paper abstracts

Note: the order of the paper abstracts follows the paper theme.

A Comparison Study of Co-simulation Frameworks for Multi-Energy Systems: The Scalability Problem

Authors Luca Barbierato[1]*, Pietro Rando Mazzarino[2], Marco Montarolo[2], Alberto Macii2, Edoardo Patti[2] and Lorenzo Bottaccioli[1]

Affiliations [1]Interuniversity Department of Regional and Urban Studies and Planning, Politecnico di Torino,Corso Duca degli, Abruzzi 24, 10129, Turin, Italy. [2]Department of Control and Computer Engineeing, Politecnico di Torino,Corso, Duca degli Abruzzi 24, 10129, Turin, Italy.

Abstract: The transition to a low-carbon society will completely change the structure of energy systems from a standalone hierarchical centralised vision to cooperative and distributed Multi-Energy Systems. The analysis of these complex systems requires the collaboration of researchers from different disciplines in the energy, ICT, social, economic, and political sectors. Combining such disparate disciplines into a single tool for modeling and analyzing such a complex environment as a Multi-Energy System requires tremendous effort. Researchers have overcome this effort by using co-simulation techniques that give the possibility of integrating existing domain-specific simulators in a single environment. Co-simulation frameworks, such as Mosaik and HELICS, have been developed to ease such integration. In this context, an additional challenge is the different temporal and spatial scales that are involved in the real world and that must be addressed during co-simulation. In particular, the huge number of heterogeneous actors populating the system makes it difficult to represent the system as a whole. In this paper, we propose a comparison of the scalability performance of two major co-simulation frameworks (i.e. HELICS and Mosaik) and a particular implementation of a well-known multi-agent systems library (i.e. AIOMAS). After describing a generic co-simulation framework infrastructure and its related challenges in managing a distributed co-simulation environment, the three selected frameworks are introduced and compared with each other to highlight their principal structure. Then, the scalability problem of co-simulation frameworks is introduced presenting four benchmark configurations to test their ability to scale in terms of a number of running instances. To carry out this comparison, a simplified multi-model energy scenario was used as a common testing environment. This work helps to understand which of the three frameworks and four configurations to select depending on the scenario to analyse. Experimental results show that a Multi-processing configuration of HELICS reaches the best performance in terms of KPIs defined to assess the scalability among the co-simulation frameworks.

Presenter: Pietro rando Mazzarino received his Master's Degree in ICT for smart societies after a Bachelor's Degree in Energy Engineering from Politecnico di Torino. He recently joined the Energy center LAB as a Ph.D. Candidate in Control and Computer Engineering. The main topics of his research are energy flexibility in urban environment and co-simulation of multi-energy systems.

Agent-based modeling (ABM) for urban neighborhood energy systems: Literature review and proposal for an all integrative ABM approach

Authors Petrit Vuthi[1], Jan Sudeikat[2]; Irene Peters[3]

Affiliations [1]Hamburg University of Applied Sciences, Competence Center for renewable energy and energy efficiency, Hamburg, 20099, Germany
[2]Hamburg University of Applied Sciences, Department of Computer Science of the faculty of Engineering and Computer Science, Hamburg, 20099, Germany
[3]HafenCity University of Hamburg, Infrastructure planning and urban engineering, Hamburg, 20457, Germany

Abstract: Realizing the energy transition in neighborhoods is attracting interest within interdisciplinary research communities. Particularly in neighborhoods, new complex challenges for local energy balancing arise when densely populated buildings are facing i.e., the so-called heat transition, increasing usage of battery-electric vehicles, and the rising expansion of renewables. Agent-based modeling (ABM) is a suitable solution for addressing various aspects related to revising policies, technologies, market mechanisms, processes, and the various stakeholder roles. In this work, we analyze peer-reviewed, open-access literature on ABM with respect to energy neighborhoods and discuss the key modeling aspects, such as model purpose and outcome, agents and decision-making logic, spatial and temporal aspects, and empirical grounding. These ABM allow for reviewing policy interventions (taxes, subsidies), local market mechanisms, local renewable energy generation, microgrids, heat transition, and neighborhood mobility. Our analysis shows a gap in the overall energy assessment, composed of the electricity, heat, and mobility sectors. Based on the reviewed studies, a consolidated ABM concept is presented that covers these sectors. Therefore, this work contributes to a better understanding of ABM and further improves research on the energy transition to a decarbonized society.

Presenter: Petrit Vuthi works as an Innovation Manager at the University of Applied Sciences Hamburg for the Competence Center for Renewable Energies and Energy Efficiency. The activities are project acquisition, networking events, and management of research projects. The main research topics are renewable energies (RE) and the integration of RE in the fields of buildings, sector coupling heat, and mobility. In 2021 he started a Ph.D. with the dissertation title "The neighborhood as a system service provider for the energy transition: Operating concept analysis of plant parks for the provision of grid services up to self-sufficiency using a coupled simulation system".

An agent-based modelling framework for the simulation of large-scale consumer participation in electricity market ecosystems

Authors Nicolas Fatras[1,2], Zheng Ma[1], Bo Nørregaard Jørgensen[1]

Affiliations [1]SDU Center for Energy Informatics, The Maersk Mc-Kinney Moller Institute, University of Southern Denmark, Odense, Denmark
[2]Sino-Danish Center for Education and Research, University of Chinese Academy of Sciences, Beijing,China

Abstract: The role of consumers as price-sensitive participants in electricity markets is considered essential to ensure efficient and secure operations of electricity systems. Yet the uncertain or unknown consequences of active market participation remain a large barrier for active consumer-side market participation. Simulations are a powerful tool to reduce this uncertainty by giving consumers an insight on the potential benefits and costs of market participation. However, the simulation setup must be adapted to each market context and each consumer market participation strategy. To simplify the simulation development process and improve the comparability of simulation results, this paper proposes a modular yet systematic electricity market modelling framework. The framework applies object-oriented programming concepts for business ecosystem modelling presented in previous works to develop an agent-based model of a consumer-centric electricity market ecosystem. The market ecosystem is represented by a multitude of interacting submarkets with their own logic. Within submarkets, context-independent and context-dependent elements are distinguished to provide model abstraction which can be adapted to different contexts. This framework is illustrated by applying it to three different submarkets in the Western Danish electricity market context: the Nordpool day-ahead market, the Nordpool intraday market, and the Frequency Containment Reserve market. The submarket role abstractions allow to benefit from the commonalities between the analysed submarkets during model implementation, while the role parametrisations allow to quickly adapt the roles to each market context. The implementation of the modelling framework in the Nordic context highlights the benefits of a modular approach in a liberalised and unbundled market context.

Presenter: Nicolas Fatras is a research assistant and PhD candidate at the Center for Energy Informatics at the University of Southern Denmark. His research focuses on the development of evaluation and simulation tools to encourage active market participation of large energy consumers. These tools are currently being implemented in the FlexPtX project within the GreenLab Skive Research Platform, and in the Sino-Danish Center project comparing the impact of the Danish and Chinese electricity market contexts on consumer flexibility potential.

Framework for Dimensioning Battery Energy Storage Systems with Applied Multi-tasking Strategies in Microgrids

Authors Troels S. Nielsen[1], Jens S. P. Thomsen[1], Athila Q. Santos[1] and Jutte Kaad[1]

Affiliations [1] SDU Center for Energy Informatics, The Maersk Mc-Kinney Moller Institute, University of Southern Denmark, Odense, Denmark

Abstract: The shifting from the traditional centralized electric sector to a distributed and renewable system presents some challenges. Battery energy storage technologies have proven effective in relieving some aspects of this transition by facilitating load control and providing flexibility to non-dispatchable renewable production. Therefore, this paper investigates how to dimension battery energy storage systems with applied multi-tasking strategies in microgrids. To this end, it proposes a framework to accurately depict how BESS can be financially and technically feasible by deploying multi-tasking strategies that fit the system characteristics of a microgrid while providing arguments for the financial incentive. The framework development is based on the principles of the analytical approach and is conceptualized in a three-part funnel structure. This framework has been tested using the case study of Aeroe microgrid and resulted in a proposed battery energy storage configuration. Based on the findings, the BESS implementation contributes to improve load behavior and to increase internal production utilization. A sensitivity analysis was performed, to investigate the robustness of the configurations. Collectively, the framework has proven to provide feasible results within a wide range of parameters. This framework could help the preliminary investigation phase when analyzing future battery energy storage system investments.

Presenter: Athila Santos is an IoT and a Smart Grids enthusiast. His area of expertise area: (1) Technology development for electric grid applications with focus on Microgrids; and (2) Large-scale deployment of IoT solutions on the building sector. Before joining SDU, Athila finished his PhD in the Electrical Engineering field, researching Information and Communication Technologies (ICT) applied to transmission systems.

Simulation of a Cellular Energy System including Hierarchies and Neighborhoods

Authors Gabriel Dengler[1], Peter Bazan[1] and Reinhard German[1]

Affiliations [1]Computer Science 7, Friedrich-Alexander-Universit¨at Erlangen-N¨urnberg, Martensstraße 3, 91058, Erlangen, Germany.

Abstract: The massive use of small energy resources and storage units causes a transition from a traditionally centralized to a decentralized energy system. To structure and coordinate the emerging changes in the energy system, the concept of Energy Cells (ECs) was developed. Several ECs can be combined to form a hierarchically superordinate EC. These hierarchically superordinate ECs can in turn be combined and thus form a complex hierarchy. An EC encapsulates coherent parts of an energy system and can communicate as well as exchange energy with other ECs at a different or the same level. It follows the idea of local balance of energy provision and demand. A network of ECs forms Cellular Energy System (CES). In this paper, we develop a concept for modeling and simulating a CES. We accomplish this by beginning with atomic components like consumers, producers, and storage units and aggregating them with Hierarchical Controllers (HCs). Such a hierarchically structured energy system is part of various proposals. However, we are able to add neighborhood relations by introducing Local Controllers (LCs). This is more realistic and also opens many degrees of freedom for control strategies in such a system. Following the recursive structure of the CES itself, we define recursive functions for visiting the CES architecture and realizing various control strategies. We evaluate our approach in a series of partially randomized scenarios, showing notable differences in the performance of the CES regarding different control strategies in a larger example. We also provide a theoretical analysis of the computational complexity of the suggested approach.

Presenter: Reinhard German received his master degree in computer science in 1991 and the PhD degree in 1994 from the Computer Science Department, Technical University of Berlin, Germany. He is a Full Professor at the Computer Networks Lab in the Department of Computer Science, University Erlangen-Nuremberg, Germany. He is also an Adjunct Professor at the Faculty of Information Technology of Monash University, Melbourne, Australia. His research interests include performance and dependability analysis of interconnected systems based on numerical analysis, network calculus, discrete-event simulation, measurements, and testing. Vehicular communications and smart energy constitute major application domains.

A Hierarchical and Modular Agent-Oriented Framework for Power Systems Co-Simulations

Authors De Vizia Claudia[1]*, Macii Alberto[1], Patti Edoardo[1] and Bottaccioli Lorenzo[2]

Affiliations [1]Dept. of Control and Computer Engineering, Politecnico di Torino, Turin, Italy.
[2]Interuniversity Dept. of Regional and Urban Studies, Politecnico di Torino, Turin, Italy.

Abstract: During the last decades, numerous simulation tools have been proposed to faithfully reproduce the different entities of the grid together with the inclusion of new elements that make the grid "smart". Often, these domain-specific simulators have been then coupled with co-simulation platforms to test new scenarios. In parallel, agent-oriented approaches have been introduced to test distributed control strategies and include social and behavioural aspects typical of the consumer side. Rarely, simulators of the physical systems have been coupled with these innovative techniques, especially when social and psychological aspects have been considered. In order to ease the re-usability of these simulators, avoiding re-coding everything from scratch, we propose a hierarchical and modular agent-oriented framework to test new residential strategies in the energy context. If needed, the presented work enables the user to select the desired level of details of the agent-based framework to match the corresponding physical system without effort to test very different scenarios. Moreover, it allows adding on top of the physical data, behavioural aspects. To this end, the characteristics of the framework are first introduced and then different scenarios are described to demonstrate the flexibility of the proposed work: i) a first stand-alone scenario with two hierarchy levels, ii) a second co-simulation scenario with a photovoltaic panel simulator and iii) a third stand-alone scenario with three hierarchy levels. Results demonstrate the flexibility and ease of use of the framework, allowing us to compare several scenarios and couple new simulators to build a more and more complex environment. The framework is in the early stages of its development. However, thanks to its properties in the future it could be extended to include new actors, such as industries, to get the full picture.

Presenter: Claudia De Vizia received her Bachelor's degree in Electronic Engineering in 2017 and her M.Sc. degree in ICT for Smart Societies at Politecnico di Torino in 2019. In November 2020, she joined the Energy Center Lab as a PhD Student. Her research activities focus on the simulation of demand-side management strategies, with particular emphasis on user behaviour.

An Adapter-Based Architecture for Evaluating Candidate Solutions in Energy System Scheduling

Authors Malte Chlosta*, Jianlei Liu, Rafael Poppenborg, Richard Lutz, Kevin Forderer, Thorsten Schlachter and Veit Hagenmeyer

Affiliations Institute for Automation and Applied Informatics (IAI), Karlsruhe Institute of Technology, Hermann-von-Helmholtz-Platz 1, 76344, Eggenstein-Leopoldshafen, Germany

Abstract: Increasing shares of volatile generation and non-steerable demand raise the need for automated control of the Energy Systems (ESs). Various solutions for management and schedule-based control of energy facilities exist today. However, the amount and diversity of applications leads to a multitude of different automated energy management solutions. Different optimization algorithms have proven more or less effective for energy management. The multitude of optimization algorithms and energy management solutions require flexible, modular, and scalable integrations. We present a novel Optimization Service (OS) for easily integrating optimization algorithms while evaluating candidate solutions in the context of ESs applications. We propose an adapter-based architecture using metadata and domain knowledge to bridge between clients, e.g. smart grid applications and optimization algorithms. The architecture interfaces different clients with optimizers in a flexible and modular way. The clients provide metadata-based descriptions of optimization jobs translated by the OS. The OS then interacts with optimizers and evaluates candidate solutions. A consistent definition of interfaces for clients and optimization algorithms facilitates modular evaluation of candidate solutions. The OS's separation of client and optimization algorithms increases scalability by managing computational resources independently. We evaluate the presented architecture for scheduling a so-called Energy Hub (EH) as a test case describing a simulation scenario of a renewable EH embedded in grid scenarios from an industrial area in Karlsruhe, Germany. The OS utilizes an Evolutionary Algorithm (EA) to optimize schedules for cost and strain on the electrical grid. The use case exemplifies the OS's advantages in a proof-of-concept evaluation.

Presenter: Malte Chlosta is a doctorate researcher at the Institute for Automation and Applied Informatics (IAI) at the Karlsruhe Institute of Technology (KIT). I have a master's degree in physics focusing on (co-) simulation and optimization. I develop software solutions to research the energy transition towards decentralized cyber-physical energy systems. My typical day includes co-simulation, optimization, energy system modeling, data handling, and rock climbing.

Automatic Process Monitoring in a District Heating Substation Utilizing a Contextual Shewhart Chart

Authors Henrik Søndergaard*, Hamid Reza Shaker, Bo Nørregaard Jørgensen

Affiliations SDU Center for Energy Informatics, The Maersk Mc-Kinney Moller Institute, University of Southern Denmark, Odense, Denmark

Abstract: Fault detection methods play a key role in enabling proactive maintenance in district heating systems. Faults are estimated to cause around 40 percent of energy consumption and it is therefore critical to employ methods to decrease this unnecessary waste of energy. For detection of these faults, a data-driven process monitoring methodology is presented which uses a modified version of the Shewhart chart, which is called contextual Shewhart chart. A process variable's normal operating range often shifts, and this can be due to external factors (e.g., outdoor temperature), and this is not captured by a regular Shewhart chart. However, the proposed contextual Shewhart chart can capture these effects by using a so-called contextual variable to vary the acceptable operational ranges, based on the identified external factor. The methodology has been applied to real data from a district heating substation and has shown promising results.

Presenter: Henrik Alexander Nissen Søndergaard is a Ph.D.-student at Center for Energy Informatics, University of Southern Denmark. His research focuses on data-driven fault detection & diagnosis and data validation methods for use in District heating- and building energy systems to enable proactive maintenance.

SGLSim: Tool for Smart Glazing Energy Performance Analysis

Authors Md Anam Raihan[1*], Kuntal Chattopadhyay[1], Aviruch Bhatia[2], Vishal Garg[1], Aftab M. Hussain[3]

Affiliations [1]Center for IT in Building Science (CBS), International Institute of Information Technology, Hyderabad-500032, India.
[2]Department of Sustainable Engineering, TERI School of Advanced Studies, New Delhi-110070, India.
[3]Center for VLSI and Embedded Systems Technology (CVEST), International Institute of Information Technology, Hyderabad-500032, India.

Abstract: A tool Smart Glazing Simulator (SGLSim), has been developed to perform parametric simulation analysis of different window systems with several window-to-wall ratios and orientations to compute and compare the annual energy performance. The net annual energy performance of the building is based on the electricity consumption in heating, cooling, interior lighting, and appliances, along with the electricity generation by the PV glazing, which is utilized to evaluate the energy performance of smart glazing. Performing parametric energy simulations and calculating the net annual electricity consumption of different combinations requires building modeling and energy simulation expertise. A web-based parametric tool can assist the user in carrying out the desired studies without requiring extensive technical knowledge. A case study is prepared for India's warm and humid climatic zone. This study examines the benefits of double pane semi-transparent photovoltaics (STPV) glazing, STPV glazing with dynamic internal blind, and electrochromic (EC) glazing over other traditional glazing systems. The study shows that the optimal net annual electricity consumption in the case of STPV windows is 10-12% less than the optimal value obtained in a simple glazing case. Additionally, the result suggested that glare-controlled interior blinds in the STPV window further reduce the net annual electricity consumption by up to 15% compared to conventional glazing. Similarly, installing the EC glazing reduces the yearly electricity consumption by up to 5% compared to standard glazing.

Presenter: Md Anam Raihan is a master's research student at International Institute of Information Technology Hyderabad, India working at Center for IT in the Building Science Laboratory. His research interests include energy efficiency in buildings, smart technologies and computer programing for sustainable development. He is receipient of prestigious Building Energy Efficiency Higher & Advanced Network (BHAVAN) fellowship from the Department of Science and Technology, Government of India and Indo-US Science and Technology Forum in 2020 to work at Lawrence Berkeley National Laboratory, University of California, Berkeley, for six-month.

Open-access Tools for the Modelling and Simulation of Electricity Markets

Authors Rui Carvalho[1], Gabriel Santos[1], Zita Vale[1*]

Affiliations [1] GECAD – Research Group on Intelligent Engineering and Computing for Advanced Innovation and Development, LASI - Intelligent Systems Associate Laboratory, Institute of Engineering, Polytechnic of Porto, Rua Dr. Antonio Bernardino de Almeida 431, 4249-015 Porto, Portugal.
* zav@isep.ipp.pt, +351 228 340 511

Abstract: Globally, the amount of renewable energy generation is increasing, which raises the complexity of operating electrical grids to maintain stability and balance and boosts the need for developing new electricity market (EM) models fitting this new reality. To test, study, and validate the possible effects of novel EM designs, simulation techniques are frequently employed. This work proposes the use of two open-access tools for the modeling and simulation of complex EMs. These are the Electricity Markets Service (EMS) and the Spine Toolbox. EMS enables the simulation of two commonly used auction-based algorithms and the execution of three European wholesale EMs. Being published as a web service facilitates its integration with other services, systems, or software agents, such as the Spine Toolbox. The Spine Toolbox, in turn, is an open-source software for complex energy systems modeling. Combining them allows the modeling and simulation of complex EMs from the wholesale to local markets, as well as testing and validating new market designs. This work's case study demonstrates how to use these tools to simulate the operation of the Iberian EM – MIBEL – for a month, using public data available from the market operator's website. The results are analyzed from the perspective of the market operator and two players, i.e., a selected buyer and seller, for a specific day and the whole month.

Presenter: Gabriel Santos received his BSc and MSc degrees in Informatics Engineering from the School of Engineering of the Polytechnic Institute of Porto (ISEP/IPP), Portugal, and his Ph.D. degree from the University of Salamanca, Spain. Currently, he is a researcher at the Research Group on Intelligent Engineering and Computing for Advanced Innovation and Development (GECAD/IPP). His research interests include multiagent systems, ontologies, electricity markets, decision support systems, and smart grids.

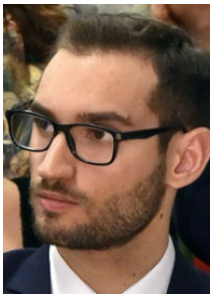
Non-Intrusive Load Monitoring techniques for the disaggregation of ON/OFF appliances

Authors Marco Castangia[1]*, Angelica Urbanelli[1], Awet Abraha Girmay[1], Christian Camarda[2], Enrico Macii[1] and Edoardo Patti[1]

Affiliations [1]Department of Control and Computer Engineering (DAUIN), Politecnico di Torino, Corso Duca degli Abruzzi, 24, 10129, Torino, Italy.
[2]Midori s.r.l., Via Paolo Borsellino, 38, 10138 Torino, Italy.

Abstract: Nowadays, Non-Intrusive Load Monitoring techniques are sufficiently accurate to provide valuable insights to the end-users and improve their electricity behaviours. Indeed, previous works show that commonly used appliances (fridge, dishwasher, washing machine) can be easily disaggregated thanks to their abundance of electrical features. Nevertheless, there are still many ON/OFF devices (e.g. heaters, kettles, air conditioners, hair dryers) that present very poor power signatures, preventing their disaggregation with traditional algorithms. In this work, we propose a new online clustering method exploiting both operational features (peak power, duration) and external features (time of use, day of week, weekday/weekend) in order to recognize ON/OFF devices. The proposed algorithm is intended to support an existing disaggregation algorithm that is already able to classify at least 80% of the total energy consumption of the house. Thanks to our approach, we improved the performance of our existing disaggreation algorithm from 80% to 87% of the total energy consumption in the monitored houses. In particular, we found that 85% of the clusters were identified by only using operational features, while external features allowed us to identify the remaining 15% of the clusters. The algorithm needs to collect on average less than 40 operations to find a cluster, which demonstrates its applicability in the real world.

Presenter: Marco Castangia received the B.S. and M.S. degrees in computer engineering from the Politecnico di Torino, where he is currently pursuing the Ph.D. degree with the Department of Control and Computer Engineering. In 2020, he joined the Department of Control and Computer Engineering, Politecnico di Torino, as a Research Assistant. His main research interests include the development of non-intrusive load monitoing algorithms and the implementation of energy data analytics.



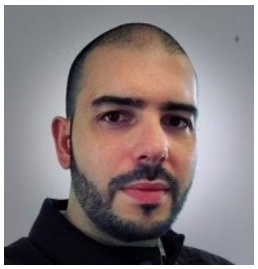
Design of Data Management Service Platform for Intelligent Electric Vehicle Charging Controller - Multi-charger Model

Authors Pedro Baptista[1], Jos´e Rosado[2,4], Filipe Caldeira[1,3] and Filipe Cardoso[1,4]*

Affiliations
[1]Viseu Polytechnic - ESTGV, Viseu, Portugal.
[2]Coimbra Polytechnic - ISEC, Coimbra, Portugal.
[3]CISeD IPV, Viseu, Portugal.
[4]INESC Coimbra, Coimbra, Portugal.

Abstract: The electric charging solutions for the residential market imply, in many situations, an increase in the contracted power in order to allow to perform an efficient charging cycle that starts when the charger is connected and ends when the VE battery is fully charged. However, the increase in contracted power is not always the best solution for faster and more efficient charging. With a focus on the residential market, the presented architecture is suitable for single-use and shared connection points, which are becoming common in apartment buildings without a closed garage, allowing for sharing the available electrical connections to the grid. The multi-charger architecture allows using one or several common charging points by applying a mesh network of intelligent chargers orchestrated by a residential gateway. Managing the generated data load involves enabling data flow between several independent data producers and consumers. The data stream ingestion system must be scalable, resilient, and extendable.

Presenter: Pedro Miguel Pereira Baptista, 38 years old with a licentiate degree from Viseu's Politechnic. Master's student at Viseu Politechnic with numerous contributions to electric vehicle charging research and development. Worked as a full-stack developer for the automotive industry. As a Devops, CI/CD, and Kubernetes enthusiast, I'm always trying to apply this knowledge to optimize sustainable mobility.



Design of an intelligent trading platform for flexibility potentials of private households in the low-voltage grid

Authors Anna Vocke[1*], Shari Alt[1], Victoria Schorr[1], Dirk Werth[1]

Affiliations [1] August-Wilhelm Scheer Institut für digitale Produkte und Prozesse gGmbH, 66123 Saarbrücken, Germany

Abstract: With an increasing number of renewable energy sources entering the energy mix, the demand for novel, smart stabilization methods for the volatile electricity grid is as pressing as ever. In this paper, we present the design of a low-threshold energy market for the intelligent trade of small flexibility potentials between grid operators and private households. The market design and the corresponding trading platform have been developed within the FlexChain project. The platform combines traditional IT-infrastructure with blockchain elements to ensure economically balanced trading of the low-price flexibility potentials. As a key element of the trading platform, the blockchain technology provides verification of and trust in trading results. The developed design will be implemented and field-tested in the upcoming project phases and economically evaluated with regard to all stakeholders. In this evaluation, special focus will be placed on the different options of blockchain integration.

Presenter: Shari Alt is a Digitization Professional at the August-Wilhelm Scheer Institut, a private research institution in Germany. Her research focuses on smart energy, sustainability and green technologies. She is currently actively involved in the role of project manager in the FlexChain research project. Ms. Alt holds a master´s degree in industrial engineering

Can we benefit from game engines to develop digital twins for planning the deployment of photovoltaics?

Authors Christian Skafte Beck Clausen[1*], Zheng Ma[1], Bo Nørregaard Jørgensen[1]

Affiliations [1] SDU Center for Energy Informatics, The Maersk Mc-Kinney Moller Institute, University of Southern Denmark, Odense, Denmark

Abstract: Digital Twins (DTs) have attracted great attention in the energy sector. Game engines have been suggested to model DTs of their physical counterparts because they provide realistic graphics, lighting-, fluid- and physics engines that simulate the real world. However, the application of game engines to develop DTs for photovoltaics (PVs) has not yet been discussed in the literature. Therefore, this paper assesses the built-in game engine features' ability to support the DT development of PVs with Unreal Engine 5. This paper mainly focuses on visual representation because the surrounding environment significantly impacts PV deployment, and the existing software tools do not allow the study of the environmental factors at the early planning phase of a project's lifecycle. Furthermore, this paper investigates the position of the sun, shadows and reflections from nearby objects that influence the PVs' power output, and if the built-in light engine can be used for planning the deployment of PVs. The result shows that in-game objects in the environment can be used to affect the simulated PV output estimate over a year. It also indicates that applying Unreal Engine 5 to model PV systems that rely on mirroring real-world behaviour is promising if accurate data is used in the modelling. Real data and mathematical PV models are necessary since Unreal Engine 5's Lumen subsystem cannot provide realistic solar radiance on PVs for a given location on earth.

Presenter: Christian Skafte Beck Clausen is a PhD-student at SDU Center for Energy Informatics. His PhD research focuses on applying the concept of Digital Twins in the context of interconnected energy systems. He earned a master's degree in Software Engineering in 2021 from the University of Southern Denmark. The master's thesis focused on reverse- and reengineering, and application of a multi-objective optimization framework written in Java. This framework was used to explore optimal dispatch of energy resources in a greenhouse subject to fluctuating market prices and energy demands.

Probabilistic FlexOffers in Residential Heat Pumps Considering Uncertain Weather Forecast

Authors Michele Albano[1], Nicola Cibin[2], Hessam Golmohamadi[3]*, Arne Skou[4]

Affiliations [1,2,3,4] Department of Computer Science, Aalborg University, 9220, Aalborg, Denmark

Abstract: The penetration of renewable energies is increasing in energy systems worldwide. Consequently, the intermittency of the energy sources raises technical challenges for sustainable energy supply. Demand-side flexibility is an effective solution to counterbalance renewable power fluctuations. In the residential sector, electrical heat pumps exhibit great flexibility potential. In this paper, a novel approach is proposed to generate FlexOffers for individual heat pumps considering the uncertain nature of weather conditions. To achieve the aim, firstly, the thermal dynamic model of residential buildings is presented mathematically. The model addresses different temperature zones. The constant coefficients of the thermal dynamics are estimated using Continuous-Time Stochastic Model (CTSM) in R software. Afterward, the building model is integrated with a success function to generate FlexOffers. The success function is comprised of two objective functions including minimization and maximization of the energy consumption of heat pumps. The FlexOffers are generated considering the existing gap between the minimum and maximum energy consumption. The patterns of energy consumption are defined based on occupants' thermal comfort temperature setpoint. The FlexOffers are programmed in UPPAAL-STRATEGO software. Finally, a high-fidelity building model with four rooms is used to examine the proficiency of the suggested approaches. The simulation results confirm that the proposed method generates flexibility potentials for the upstream network in both optimistic and pessimistic states of energy consumption patterns.

Presenter: Hessam Golmohamadi, SMIEEE, has BSc, MSc, and Ph.D. in Power Electrical Engineering. He joined the Department of Energy, AAU, Denmark in 2018 to finalize his Ph.D. thesis. His research interests are intelligent energy systems, energy/demand flexibility, and smart grids. In 2020, he joined the Department of Computer Science, AAU as a postdoctoral fellow. Currently, he is working on Danish and EU projects, including FED and FEVER. The projects discuss flexibility potentillas of energy management systems, especially in residential heating systems.

Potentials of game engines for wind power digital twin development: an investigation of the Unreal engine

Authors Jonas Vedsted Sørensen[1*], Zheng Ma[1], Bo Nørregaard Jørgensen[1]

Affiliations [1] SDU Center for Energy Informatics, The Maersk Mc-Kinney Moller Institute, University of Southern Denmark, Odense, Denmark

Abstract: Digital twin technologies have become popular in wind energy for monitoring and what-if scenario investigation. However, developing a digital representation of the wind is challenging, especially due to the digital twin platform constraints. Game engines might be possible to solve this issue, especially since game engines have been used for product design, testing, prototyping, and also digital twins. Therefore, this study investigates the potential of developing a digital twin of wind power in the Unreal game engine. A case study of two types of wind turbines (Vestas V164-8 and Enercon E-126 7.580) and one location (Esbjerg, Denmark) is chosen for this study. The digital twin includes the environment with historical wind data and the visual representation of the wind turbine with a wind power production model and the estimated production in the given wind conditions of the area. The results show that game engines are viable for building entire digital twins where a realistic graphical user interface is required. Unreal Engine 5 provides the tools for modelling the landscape, surrounding water, and lighting. In addition, the Unreal Engine ecosystem provides vast amounts of content, such as 3D assets and game logic plugins, easing the digital twin development. The results prove that digital twins built in Unreal Engine 5 have great potential development of digital twins and user interfaces for communicating with a digital twin. The developed digital twin allows for further extension to benefit future digital twins utilizing wind turbines.

Presenter: Jonas Vedsted Sørensen is currently a PhD fellow at Center for energy Informatics, University of Southern Denmark. His research interests are in digital twin architecture patterns for improving development and qualitative aspects of digital twins. He obtained his MSc in Software Engineering at The University of Southern Denmark in 2021.

Peer-to-Peer Energy Trading Optimization in Energy Communities using Multi-Agent Deep Reinforcement Learning

Authors Helder Pereira[1], Luis Gomes[1], Zita Vale[1*]

Affiliations [1] Intelligent Systems Associated Laboratory (LASI), Research Group on Intelligent Engineering and Computing for Advanced Innovation and Development (GECAD), Polytechnic of Porto (P.PORTO), Rua Dr. António Bernardino de Almeida 431, 4200-072 Porto, Portugal

Abstract: In the past decade, the global distribution of energy resources has expanded significantly. The increasing number of prosumers creates the prospect for a more decentralized and accessible energy market, where the peer-to-peer energy trading paradigm emerges. This paper proposes a methodology to optimize the participation in peer-to-peer markets based on the double-auction trading mechanism. This novel methodology is based on two reinforcement learning algorithms, used separately, to optimize the amount of energy to be transacted and the price to pay/charge for the purchase/sale of energy. The proposed methodology uses a competitive approach, and that is why all agents seek the best result for themselves, which in this case means reducing as much as possible the costs related to the purchase of energy, or if we are talking about sellers, maximizing profits. The proposed methodology was integrated into an agent-based ecosystem where there is a direct connection with agents, thus allowing application to real contexts in a more efficient way. To test the methodology, a case study was carried out in an energy community of 50 players, where each of the proposed models were used in 20 different players, and 10 were left without training. The players with training managed, over the course of a week, to save 44.65 EUR when compared to a week of peer-to-peer without training, a positive result, while the players who were left without training increased costs by 17.07 EUR.

Presenter: Helder Pereira is graduated in Computer Engineering and is currently a student in the Polytechnic of Porto, in the Masters of Artificial Intelligence Engineering. Besides that, he currently has a research scholarship in GECAD, an innovation and research group affiliated with the Polytechnic of Porto. His research till today focuses on integrating artificial intelligence algorithms and models, more specifically machine learning, decision support and optimization, into energy systems, but his interests relate to the whole artificial intelligence areas and their possible applications.

Investigation on Air Conditioning Load Patterns and Electricity Consumption of Typical Residential Buildings in Tropical Wet and Dry Climate in India

Authors Pavan Ramapragada[1], Dharani Tejaswini[1*],Vishal Garg[1], Jyotirmay Mathur[2], Rajat Gupta[3]

Affiliations [1]Center for IT in Building Science, International Institute of Information Technology, Hyderabad-500032, India.
[2]Center for Energy and Environment, Malaviya National Institute of Technology, Jaipur-302017, India.
[3]Low Carbon Building Research Group, Oxford Institute for Sustainable Development, School of Architecture, Oxford Brookes University, Oxford-OX3 0BP, United Kingdom

Abstract: The residential sector accounts for around 24% of the total electricity consumption in India. Recent studies show that Air Conditioners (ACs) have become a significant contributor to residential electricity consumption. Further, it is predicted that by 2037, the demand for ACs will increase by four times due to their affordability and availability. Not many studies have been found on residential AC usage patterns and the factors (AC load, setpoint, hours of usage) that influence household electricity consumption. This paper investigates the residential AC usage patterns and AC's contribution to total residential electricity consumption. Twenty-five urban homes from a wet and dry climatic region of India were monitored for nine months (in 2019) to determine overall household electricity consumption patterns, AC usage, and indoor environment during summer, monsoon, and winter. Analysis of seasonal consumption patterns shows a significant difference in electricity usage between homes with ACs and homes without ACs during the summer season. The average electricity consumption for AC homes was 15.1 kWh/day during summer, 6.6 kWh/day during monsoon, and 6.1 kWh/day during the winter season. Results showed that AC alone contributed to 39% of the total household consumption in summers. The peak AC usage in all homes is observed during sleep hours which was generally between 10:00 pm - 6:00 am and the average AC runtime was 6.2 hours. The average indoor temperature was recorded as 26.9°C during the AC ON period. The AC peak load, i.e., the maximum electricity demand during the AC ON period, is 1.7 kW on average during the study period. The average annual consumption of homes with ACs was 2881 kWh, and for non-AC homes, the consumption was 2230 kWh. Findings from our analysis provide a detailed understanding of AC consumption profiles and the difference in electricity consumption characteristics between AC and non-AC homes across different seasons.

Presenter: Pavan Ramapragada is a master's research student at International Institute of Information Technology Hyderabad, India (IIIT-H) working at 'Centre for IT in Building Science Laboratory. His research interests include energy efficiency in buildings, data handling, analysis and visualization in the field of Building Sciences.

Residential Electricity Current and Appliance Dataset for AC-event Detection from Indian Dwellings

Authors Dharani Tejaswini[1*] ,Pavan Ramapragada[1], Sraavani Gundepudi[1], Prabhakar Rao Kandukuri[1],Vishal Garg[1], Jyotirmay Mathur[2], Rajat Gupta[3]

Affiliations

[1]Center for IT in Building Science, International Institute of Information Technology, Hyderabad-500032, India.
[2]Center for Energy and Environment, Malaviya National Institute of Technology, Jaipur-302017, India.
[3]Low Carbon Building Research Group, Oxford Institute for Sustainable Development, School of Architecture, Oxford Brookes University, Oxford-OX3 0BP, United Kingdom

Abstract: Air Conditioners (ACs) have become a major contributor to residential electricity consumption in India. Non-intrusive Load Monitoring (NILM) can be used to understand residential AC use and its contribution to electricity consumption. NILM techniques use ground truth information along with meter readings to train disaggregation algorithms. There are datasets available for disaggregation, but no dataset is available for a hot tropical country like India especially for AC event detection. Our dataset's primary objective is to help train NILM algorithms for AC event detection and compressor operations. The dataset comprises of home-level electrical current consumption and manually tagged AC ground truth (ON/OFF status) data at 1-minute interval, indoor environment temperature and relative humidity readings at 5-min interval and dwelling, AC and household characteristics. The data was collected from 11 homes located in a composite climate zone-Hyderabad, India for 19 summer days (May) 2019 . The dataset consists of 1.6 million data points and 450 AC cycles with each cycle having a runtime of more than 60 minutes (> 2000 compressor ON/OF cycles). Public availability of such a dataset will allow researchers to develop, train and test NILM algorithms that recognize AC and identify compressor operations.

Presenter: Dharani Tejaswini is a Ph.D. scholar in the field of Computer Science and Engineering at the Centre for IT in Building Science lab, IIIT-Hyderabad, India. She is the recipient of IHub-data fellowship established by IIIT-Hyderabad under the National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS) scheme. Her current research interests include NILM (Non-Intrusive Load Monitoring) for residential buildings and building energy simulations using multi-agent systems.

Long Short-Term Memory on Electricity Load Forecasting: Comparison of Feature Scaling Techniques

Authors Nur Shakirah Md Salleh[1*], Bo Nørregaard Jørgensen[2], Wahidah Hashim[3]

Affiliations [1]College of Computing and Informatics, Universiti Tenaga Nasional, Kajang, 43000, Malaysia
[2] SDU Center for Energy Informatics, The Maersk Mc-Kinney Moller Institute, University of Southern Denmark, Odense, Denmark
[3]College of Computing and Informatics, Universiti Tenaga Nasional, Kajang, 43000, Malaysia

Abstract: Electricity load prediction can assist utility companies to estimate the electric power to be generated. The study used historical electricity load data from a residential area in Denmark, and employed a single feature, i.e., the previous hour's electricity load, to predict the current electricity load demand. Due to the different data ranges found in the dataset, this manuscript intended to prove the importance of feature scaling technique selection that would impact the prediction results. A comparison was made on the prediction results of the scaled dataset using the MinMax Scaler, Robust Scaler, and Power Transformer Scaler. The machine learning algorithm, Long Short-Term Memory (LSTM), was applied because the input and output data were in time series, and the estimation of electricity load value was the expected output. It was found that the Robust Scaler scored the highest R-squared value between 0.90 and 0.95. The R-squared value of the Power Transformer Scaler was between 0.89 and 0.92, whereas the R-squared value of the MinMax Scaler was 0.85.

Presenter: Nur Shakirah Md Salleh has 10 years' experience lecturer with a demonstrated history of working in education. Teaches various Computer Science courses such as Mobile Application Development, Parallel Computing, Machine Learning, and Computer Organization. Research interest in energy and machine learning. Passionate about invention by joining some innovation competitions and winning the national and international competition - 1 Gold Medal and Special Award by JIPA in MTE 2022, 1 Silver Medal in ITEX 2016, 1 Silver Medal and 2 Bronze Medals in ICTREC 2017. Ph.D. candidate in UNITEN, Malaysia.

Anomaly detection in quasi-periodic energy consumption data series: a comparison of algorithms

Authors Niccolo Zangrando, Piero Fraternali, Marco Petri, Nicol`o Oreste Pinciroli Vago and Sergio Luis Herrera Gonzalez*

Affiliations Dipartimento di Elettronica, Informazione e Bioingegneria, Politecnico di Milano, 20133, Milan, Italy

Abstract: The diffusion of domotics solutions and of smart appliances and meters enables the monitoring of energy consumption at a very fine level and the development of forecasting and diagnostic applications. Anomaly detection (AD) in energy consumption data streams helps identify data points or intervals in which the behavior of an appliance deviates from normality and may prevent energy losses and break downs. Many statistical and learning approaches have been applied to the task, but the need remains of comparing their performances with data sets of different characteristics. This paper focuses on anomaly detection on quasi-periodic energy consumption data series and contrasts 12 statistical and machine learning algorithms tested in 144 different configurations on 3 data sets containing the power consumption signals of fridges. The assessment also evaluates the impact of the length of the series used for training and of the size of the sliding window employed to detect the anomalies. The generalization ability of the top five methods is also evaluated by applying them to an appliance different from that used for training. The results show that classical machine learning methods (Isolation Forest, One-Class SVM and Local Outlier Factor) outperform the best neural methods (GRU/LSTM autoencoder and multistep methods) and generalize better when applied to detect the anomalies of an appliance different from the one used for training.

Presenter: Marco Petri is a MSc student in Computer Science and Engineering at Politecnico di Milano. He has followed the AI track and recently started his thesis work on anomaly detection in time series. His main interests are machine and deep learning methods and their application in industrial processes.

Revealing interactions between HVDC cross-area flows and frequency stability with explainable AI

Authors Sebastian Putz[1],[2]*, Benjamin Schafer[3], Dirk Witthaut[1], [2] and Johannes Kruse[1], [2]

Affiliations [1]Forschungszentrum Julich, Institute for Energy and Climate Research - Systems Analysis and Technology Evaluation (IEK-STE), 52428 Julich, Germany
[2]Institute for Theoretical Physics, University of Cologne, 50937 Koln, Germany
[3]Karlsruhe Institute of Technology, Institute for Automation and Applied Informatics (IAI),76344 Eggenstein-Leopoldshafen, Germany

Abstract: The transition to renewable energy sources challenges the operation and stability of the electric power system. Wind and solar power generation are volatile and uncertain, and energy sources may be located far away from the centers of the load. High Voltage Direct Current (HVDC) lines enable long-distance power transmission at low losses, both within and between different synchronous power grids. HVDC interconnectors between different synchronous areas can be used to balance volatile generation by leveraging their fast control behavior, but rapid switching may also disturb the power balance. In this article, we analyze the interaction of HVDC interconnector operation and load-frequency control in different European power grids from operational data. We use explainable machine learning to disentangle the various influences affecting the two systems, identify the key influences, and quantify the interrelations in a consistent way. Our results reveal two different types of interaction: Market-based HVDC flows introduce deterministic frequency deviations and thus increase control needs. Control-based HVDC flows mitigate frequency deviations on one side as desired but generally disturb frequency on the other side. The analysis further provides quantitative estimates for the control laws and operation strategies of individual HVDC links, for which there is little public information. Furthermore, we quantify the importance of HVDC links for the frequency dynamics, which is particularly large in the British grid.

Presenter: Sebastian Pütz obtained his Bachelor of Science in Physics with a focus on quantum information systems at the University of Cologne. He is now doing his Master of Science in Cologne. In November 2021 Sebastian joined the research group of Prof. Dirk Witthaut at the Research Centre in Jülich. For his master's thesis, he aims to use methods from explainable AI (XAI) and data science to investigate power system operation.

Recursive training based Physics Inspired Neural Network for Electric Water Heater modeling

Authors Surya Venkatesh Pandiyan[1]* and Jayaprakash Rajasekharan[2]

Affiliations [1]Department of Electric Power Engineering, NTNU, 7491, Trondheim, Norway.
[2]Department of Electric Power Engineering, NTNU, Trondheim, Norway

Abstract: Aggregating flexibility from residential electric water heaters (EWHs) is fast gaining commercial interest. Flexibility modeling of an EWH involves highly precise and quick simulation of EWH water temperature using the EWH thermal dynamics model for various flexibility control actions. Since EWH tank water temperature data is usually unavailable or costly to obtain, developing an accurate and computationally inexpensive EWH thermal dynamics model with limited sensor data is essential for devising advanced control strategies for EWH flexibility aggregation. In this paper, we present a novel recursive training-based unsupervised physics-informed neural network (PINN) model for predicting tank water temperature which requires only historical EWH power consumption data to train the model. PINN models enable the integration of domain knowledge from traditional physical processes and methods into neural network (NN) models. Single-zone thermal grey-box differential equation model (DEM) is used as the basis to develop and demonstrate proof-of-concept of the proposed approach. Physics from the single-zone model is encoded into the PINN loss function to incorporate domain knowledge and the PINN architecture is structured to mimic the single-zone DEM. The recursive training approach enables the use of previous-step water temperature as an input to the simulation model. Two separate models for EWH ON- and OFF-states are developed and trained with real-world EWH power consumption data. Water temperature prediction results indicate that the proposed approach has similar performance as the traditional single-zone DEM model, thereby demonstrating the ability of the proposed model to learn the underlying physics behind the single-zone model without water temperature data. The proposed model has high accuracy and performs well outside the control set point temperatures indicating its suitability for simulating load shifting and other DR events. Additionally, EWH simulation results for two different scenarios with different water demand compositions are presented to study the effects of propagation errors on temperature prediction. The proposed approach paves the way for developing advanced EWH flexibility modeling tools for the aggregator to precisely control a large portfolio of EWHs considering user comfort and rebound effects.

Presenter: Surya Venkatesh Pandiyan is currently pursuing Ph.D. in electrical engineering at NTNU. His Ph.D. research is focused on developing informatics-based methods for activating demand-side flexibility in balancing markets. His research interests include machine learning, reinforcement learning for flexibility activation, smart energy systems, energy forecasting, etc. He has a master's in energy engineering and management. For his master thesis, he worked on Non-intrusive load monitoring using a variational autoencoder.

Evaluation of Neural Networks for Residential Load Forecasting and the Impact of Systematic Feature Identification

Authors Nicolai Bo Vanting[1*], Zheng Ma[1], Bo Nørregaard Jørgensen[1]

Affiliations [1] SDU Center for Energy Informatics, The Maersk Mc-Kinney Moller Institute, University of Southern Denmark, Odense, Denmark

Abstract: Due to political decisions and ambitions, the energy system faces challenges in the coming years. Especially distribution system operators are affected by the challenges because they maintain grid control. Accurate predictions of the electricity load can help DSOs better plan and maintain their grid. The study aims to test a systematic data identification and selection process to forecast the electricity load of Danish residential areas. The five-ecosystem CSTEP framework maps relevant independent variables on the cultural, societal, technological, economic, and political dimensions. Based on the literature, a recurrent neural network (RNN), long-short-term memory network (LSTM), gated recurrent unit (GRU), and feed-forward network (FFN) are evaluated and compared. The models are trained and tested using different data inputs and forecasting horizons to assess the impact of the systematic approach and the practical flexibility of the models. The findings show that the models achieve equal performances of around 0.96 adjusted R2 score and 4-5% absolute percentage error for the one-hour predictions. Forecasting 24 hours gave an adjusted R2 of around 0.91 and increased the error slightly to 6-7% absolute percentage error. The impact of the systematic identification approach depended on the type of neural network, with the FFN showing the highest increase in error when removing the supporting variables. The GRU and LSTM did not rely on the identified variables, showing minimal changes in performance with or without them. The systematic approach to data identification can help researchers better understand the data inputs and their impact on the target variable. The results indicate that a focus on curating data inputs affects the performance more than choosing a specific type of neural network architecture.

Presenter: Nicolai Bo Vanting is a Ph.D. student at the Maersk Mc-Kinney Moller Institute, University of Southern Denmark, and holds an MSc in Data Science from the University of Southern Denmark. He focuses on research relating to energy load forecasting by leveraging complex data sources and applying machine learning algorithms. His Ph.D. project is titled "Big data-driven hybrid AI method for energy demand forecasting and operational planning in industrial greenhouse production," which aims to use artificial intelligence methods for energy demand forecasting in the industrial greenhouse domain.

Identification of natural disaster impacted electricity load profiles with k means clustering algorithm

Authors Simon Hedegård Jessen[1*], Zheng Ma[1], Francisco Danang Wijaya[2], Juan Vasquez[3], Josep Guerrero[3], Bo Nørregaard Jørgensen[1]

Affiliations

[1] SDU Center for Energy Informatics, The Maersk Mc-Kinney Moller Institute, University of Southern Denmark, Odense, Denmark
[2]Department of Electrical and Information Engineering, Universitas Gadjah Mada, Yogyakarta, 55281, Indonesia

Abstract: Natural disasters threat the resilience of the electricity system. However, little literature has investigated the electricity system's recovering process and progress after natural disasters' hit which strongly influence the system operators' planning and quality of the security of supply for the electricity customers. To fill the research gap, this paper applies an unsupervised machine learning method, the k means clustering algorithm, to investigate the normal/abnormal electricity load profiles, identify natural disaster- and electrical fault-impacted electricity load profiles with a case study of the Lombok electricity system, Indonesia, and½-hourly electricity load data from 2015 until 2021. The results show that electricity consumption in Lombok has increased over the years, which match the installed production capacity of Lombok. The results prove that the disturbance-induced electricity load patterns and especially natural disaster-impacted load profiles can be identified by the k means clustering algorithm. Especially, the pre-, during, and post-natural disaster impacted load patterns can be portrayed. Furthermore, the investigation results regarding the impacts of natural disasters and electrical faults on the performance of the electricity system, show that the natural disaster-induced load reductions and electrical fault-induced load reductions differ from the short and long-term perspectives. Moreover, the results can facilitate the electricity system operators to better understand the load patterns, predict ND strikes' impact on the electricity system and conduct better long-term energy management strategies.

Presenter: Simon Hedegård Jessen is a PhD researcher primarily focusing on sustainable and resilient energy system transformation, at the SDU Center for Energy Informatics. His research targets preservation of the security of supply during large disruptions (i.e., natural disasters, extreme weather events, cyber-attacks) for particularly electricity networks ranging in size from small island-mode microgrids to larger, interconnected TSO networks. Prior to joining the Center, he has been studying BSc and MSc in energy systems engineering (University of Southern Denmark) which led to acquired competences within techno-economic feasibility evaluation of distributed energy resources implementation in energy system projects. In parallel, he worked as a student worker for Energinet and SDU Center for Energy Informatics, effectuating tasks within ancillary services delivery monitoring and energy ecosystems.

Can electric vehicles be an alternative for traditional fossil-fuel cars with the help of renewable energy sources towards energy sustainability achievement?

Authors Abbas M. Al-Ghaili[1,*], Hairoladenan Kasim[2], Hazleen Aris[1,3], and Naif M. Al-Hada[4,5]

Affiliations
[1]Institute of Informatics and Computing in Energy (IICE), Universiti Tenaga Nasional (UNITEN), 43000 Kajang, Selangor, Malaysia
[2]Department of Informatics, College of Computing and Informatics (CCI), UNITEN, 43000 Kajang, Selangor, Malaysia
[3]Department of Computing, College of Computing and Informatics (CCI), UNITEN, 43000 Kajang, Selangor, Malaysia
[4]Shandong Key Laboratory of Biophysics, Institute of Biophysics, Dezhou University, Dezhou 253023, China
[5]Electronics and Communication Engineering Department, Faculty of Electrical and Electronics Engineering, Istanbul Technical University, 34467 Sarıyer, Turkey

Abstract: It's been possible to use numerous EV technologies to help with various problems and challenges, including the need for quick EV charging stations. However, there is a worry over the viability and applicability of EV-applied technologies that are ideally suited towards greater and more efficient usage of RESs in order to either attain or contribute to energy sustainability. The purpose of this study is to identify and assess the most recent advances and methodologies in the field. In this article, we will discuss a variety of EV technologies that have been used in the past and contributed to the development of RESs. It is found that EVs can be an effective alternative for currently used fossil-fuel vehicles due to a set of reasons highlighted in this review including fast EV charging stations, efficient design for PV solar panels, and effective utilization of RESs. The contribution of this review article is that, a number of the benefits of using the employed EVs techniques for the purpose of utilizing renewable energy sources (RESs) towards the accomplishment of a sustainable energy goal for a green environment in the so foreseeable have been highlighted; aiming to provide a larger variety of readers insights and suggestions for future research development.

Presenter: Dr. Abbas M. Al-Ghaili participated and represented UNITEN in numerous international conferences related to energy, IoT, image processing, and security related researches. He participated in several international exhibitions dedicated for technological inventions and potential products. Dr. Al-Ghaili has authored and co-authored a total of 59 publications; including ISI- and Scopus-indexed journals, Scopus-indexed conferences, and Scopus-indexed book chapters. He has been granted international and local research grants and projects. Dr. Al-Ghaili has been awarded the “Best Paper Nominee” in an international conference in 2019. His research interests include energy informatics, image processing, computer security, and computer vision.

Impact of COVID-19 on Energy Consumption in a Residential Complex in Hyderabad, India

Authors Kuntal Chattopadhyay [1*], Vishal Garg [1], Praveen Paruchuri [2], Jyotirmay Mathur [3], Srinivas Valluri [4]

Affiliations
[1]Center for IT in Building Science, International Institute of Information Technology- Hyderabad, Hyderabad, 500032 India.
[2]Machine Learning Lab, International Institute of Information Technology-Hyderabad, Hyderabad, 500032, India.
[3]Centre for Energy and Environment, Malaviya National Institute of Technology Jaipur, Jaipur, 302017 India.
[4]CEO- Synergy infra consultants (Pvt)Ltd, Hyderabad, 500082, India.

Abstract: When the Indian government declared the first lockdown on 25 March 2020 to control the increasing number of COVID-19 cases, people were forced to stay and work from home. The aim of this study is to quantify the impact of stay-at-home orders on residential Air Conditioning (AC) energy and household electricity consumption (excluding AC energy). This was done using monitored data from 380 homes in a group of five buildings in Hyderabad, India. We gathered AC energy and household electricity consumption data at a 30-minute interval for each home individually in April 2019 and April 2020. Descriptive and inferential statistical analysis was done on this data. To offset the difference in temperatures for the month of April in 2019 and 2020, only those weekdays were selected where the average temperature in 2019 was same as the average temperature in 2020. The study establishes that the average number of hours the AC was used per day in each home increased in the range 4.90 – 7.45% depending on the temperature for the year 2020. Correspondingly, the overall AC consumption increased in the range 3.60 – 4.5%, however the daytime (8:00 AM to 8:00 PM) AC energy consumption increased in the range 22 – 26% and nighttime (8:00 PM to 8:00 AM) AC energy consumption decreased by 5-7% in the year 2020. The study showed a rise in household electricity consumption of about 15% for the entire day in the year 2020. The household electricity consumption increased during daytime by 22- 27.50% and 1.90- 6.6% during the nighttime. It was observed that the morning household electricity peak demand shifted from 7:00 AM in 2019 to 9:00 AM in 2020. Conversely, the evening peak demand shifted from 9:00 PM in 2019 to 7:00 PM in 2020. An additional peak was observed during afternoon hours in the lockdown.

Presenter: Kuntal Chattopadhyay has done Bachelor of Technology in Civil Engineering from Jawaharlal Nehru Technological University-Hyderabad, India. He is currently pursuing his master's from International Institute of Information Technology Hyderabad, India at Center for IT in the Building Science Laboratory. His research interests include building energy performance, building automations, renewable energy, and fault detections. He has prepared calibrated test bed during the project "Building Integrated Photovoltaics" funded by Department of Science and Technology, India. Further, he has prepared and analysed a simulation model during the project "Development and performance analysis of semi-transparent Solar Photo-voltaic facade system" using EnergyPlus. He has been also acknowledged in the book "Building Energy Simulations Vol-2", as he was one of the reviewers of the book.

A probabilistic approach to reliability analysis of district heating networks incorporating censoring: A report of implementation experiences

Authors Lasse Kappel Mortensen[1*], Hamid Reza Shaker[1], Christian T. Veje[1]

Affiliations [1] SDU Center for Energy Informatics, The Maersk Mc-Kinney Moller Institute, University of Southern Denmark, Odense, Denmark

Abstract: Reliability analysis has the potential to provide actionable insight into the failure probability of assets in district heating networks. Information about the failure rate and its trend may help operators and asset managers replace assets at the optimal time, which can increase the security of supply, save resources, and reduce operational and maintenance costs. In this paper, we employ a probabilistic proportional hazard modeling approach to reliability analysis, which has not been used for district heating pipes before, explore its potential and report our experiences. The model allows us to model the time-dependent survival probability of pipe assets as a function of asset-related and environmental predictors which have been shown to influence failure probability in previous studies. We find that the application of the model in this domain is challenged by several issues pertaining to data, one of which we attempt to remedy with a simple imputation strategy.

Presenter: Lasse Kappel Mortensen got his master's degree in Energy Technology engineering from SDU in 2021. He currently enrolled as a Ph.D. student at the Center for Energy Informatics at the Maersk Mc-Kinney Möller Institute. His Ph.D. project focuses on data-driven methods for proactive and predictive maintenance of energy systems, and his research interests include energy systems, machine learning, statistics, and data-level techniques to handle scarce and missing data.

Application of Energy Informatics in Danish Research Projects

Authors Daniel Anthony Howard[1*], Zheng Ma[1], Bo Nørregaard Jørgensen[1]

Affiliations [1] SDU Center for Energy Informatics, The Maersk Mc-Kinney Moller Institute, University of Southern Denmark, Odense, Denmark

Abstract: To enable sound scientific research in future energy informatics projects, it is necessary to obtain an overview of the current state of the research field to identify unaddressed gaps and challenges. Therefore, this paper aims to investigate the research trends and achievements within energy informatics in a Danish context within the last three decades. This paper reviews 207 energy informatics projects collected until the second quarter of 2022. Quantitative analysis results show that most projects have focused on applying energy informatics through energy-aware control of end-user consumption. The qualitative review finds an emphasis on data usage and end-users which aligns with the quantitative review. Furthermore, it tends to focus on specific end-users, e.g., buildings and heat pumps. Four overall recommendations are established: (I) Increased emphasis on research for sector coupling to aid in unlocking energy system flexibility, (II) project data value chain output, focusing on structuring and managing the data to make it applicable for future re-use, (III) utilizing industrial loads and incorporating an end-user perspective, (IV) inclusion of research institutions for the improved overall output of the projects through interdisciplinary solutions.

Presenter: Daniel Anthony Howard's research focuses on data-driven solutions for unlocking industrial energy flexibility potentials in the renewable energy transition. The industrial energy flexibility potentials are established using a multi-agent system framework for digital twin solutions in the production flow process. The agent-based Digital Twin is enabled through multi-method modeling, Big Data Analytics, simulation, and AI. Hence, the research bridges the need for energy flexibility and the underlying restrictions imposed by quality requirements and schedules in a given production flow, providing stakeholders with an opportunity for what-if scenario testing, decision support, and production process flow optimization.

Ecosystem-driven business opportunity identification method and web-based tool with a case study of the electric vehicle home charging energy ecosystem in Denmark

Authors Zheng Ma[1*], Kristoffer Christensen[1], Thomas Finch Rasmussen [2], Bo Nørregaard Jørgensen[1]

Affiliations [1] SDU Center for Energy Informatics, The Maersk Mc-Kinney Moller Institute, University of Southern Denmark, Odense, Denmark
[2]Energinet, Fredericia, Denmark

Abstract: Understanding the local needs and challenges is critical for technology adoption in the energy sector. However, it is still a big challenge for most ecosystem stakeholders. Furthermore, technology adoption theories have mainly focused on the technology itself, and the business ecosystem perspective has been neglected. Therefore, this paper proposes an ecosystem-driven business opportunity identification method, a systematic approach for ecosystem stakeholders to conduct business opportunity analysis and evaluation based on the CSTEP ecosystem analysis and evaluation method. This method includes four correlated steps: Step 1: Identify the five CSTEP dimensions of the business ecosystem; Step 2: Identify potential changes in the business ecosystem; Step 3: Identify future ecosystem trends and timeline; and Step 4: Select business opportunities. A web-based tool called CSTEP business opportunity identifier is developed for implementing the proposed method. A case study of the electric vehicle (EV) home charging energy ecosystem in Denmark is applied and demonstrates the application of the proposed method and the implementation of the developed web-based tool. Three potential solutions and their value propositions are identified in the case study: 1) intelligent decentralized EV charging algorithms considers electricity price signals, distribution tariffs, and CO2 emission signals, so EV users can have optimal cost for EV charging and CO2 emission reduction. 2) The Intelligent centralized EV charging algorithms enable the distribution system operators to avoid grid overloads and postpone the grid upgrade. 3) The Intelligent centralized EV charging algorithms enable charging box providers to aggregate EVs, participate in the ancillary service market, or provide Vehicle-to-Grid services. This result also illustrates the importance of digitalization in the energy transition, especially for energy efficiency, energy flexibility, and CO2 emission reduction.

Presenter: Kristoffer Christensen just finished his Ph.D in Energy Informatics at the Center for Energy Informatics, the University of Southern Denmark. His Ph.D focus has been to develop a multi-agent based framework for evaluating digital energy solutions and adoption strategies. The developed framework has been applied to the energy ecosystem, electric vehicle charging strategies, and dynamic distribution tariffs, etc. He has been the correspondent author and co-author for 12 publications during his Ph.D. Kristoffer holds a M.Sc. and B.Sc. in Energy Technology Engineering from the University of Southern Denmark.

Survey data on university students' experience of energy control, indoor comfort, and energy flexibility in campus buildings

Author Zheng Ma

Affiliation SDU Center for Energy Informatics, The Maersk Mc-Kinney Moller Institute, University of Southern Denmark, Odense, Denmark

Abstract: Due to large energy consumption and equipped building control systems, the majority of campus buildings have the potential to increase energy efficiency and provide energy flexibility. Among the three main types of occupants in the campus buildings (researchers/teachers, students, administration/management), students spend most of their time on learning activities in the campus buildings, and the energy performance can influence their learning performance. Therefore, this paper conducts a questionnaire targeting student occupants at a large engineering faculty in a Danish university to investigate occupants' experience of energy control, indoor comfort, and options of energy flexibility in campus buildings. In total, 267 fully completed and usable questionnaires were received. The dataset is available in .xlsx format, and the questionnaire that was used to collect the data is also provided together.

Presenter: Dr. Zheng Grace Ma, Associate Professor at the SDU Center for Energy Informatics, The Mc-Kinney Moller Institute, University of Southern Denmark. She is the research lead of SDU strategic research areas of digital twins for industrial processes, value chains, and business ecosystems. She develops a multi-dimensional, multi-criteria evaluation and forecasting method for business ecosystem impact analysis and long-term prediction. Her research combines multiple methods (agent-based simulation, discrete event simulation, big data analytics, and scientific qualitative and quantitative methods) to investigate future scenarios and evaluate solutions (algorithm, software, technologies, and services) and business models in targeted ecosystems.

CELSIUS: an international project providing integrated, systematic, Cost-effective large-scale IoT solutions for improving energy efficiency of medium- and large-sized buildings

Authors Zheng Ma[1], Athila Quaresma Santos[1], Hamid Reza Shaker[1], Salman Yussof[2], Poul Møller Eriksen[3], Jens Hornum[4], Bo Nørregaard Jørgensen[1*]

Affiliations
[1] SDU Center for Energy Informatics, The Maersk Mc-Kinney Moller Institute, University of Southern Denmark, Odense, Denmark
[2]Institute of Informatics and Computing in Energy, University Tenaga Nasional, Jalan Ikram-Uniten, 43000 Kajang, Selangor, Malaysia
[3]Develco Products A/S, Tangen 6, 8200 Aarhus, Denmark
[4]Elbek & Vejrup A/S, Tangen 6, 8200 Aarhus, Denmark

Abstract: Worldwide, buildings consume about 40 percent of the overall energy resources and contribute to an average of 30 percent of the global carbon emission. Hence, technologies for improving the energy efficiency of buildings play an essential role in the global fight against climate change. The CELSIUS project aims to improve the energy efficiency and indoor climate of medium to large sized commercial and public buildings by developing an integrated system solution that consists of 1) an IoT-enabled and cloud-based platform for monitoring and diagnostics of building energy performance and indoor climate quality, 2) a middleware software platform for cost-effective large-scale deployment of wireless sensors and gateways, and 3) an IoT network management platform for cost-efficient life-cycle maintenance of sensors and gateways. The integrated system solution will be deployed and demonstrated in a 6000 m2 building in Aarhus, Denmark, and an 18000 m2 building in Kuala Lumpur, Malaysia. By choosing buildings located in different climate zones on different continents allows the developed system solution to be tested under realistic conditions for the international export market.

Presenter: Professor, Dr. Bo Nørregaard Jørgensen is founder and head of Center for Energy Informatics at the University of Southern Denmark. Center for Energy Informatics is an interdisciplinary research center focusing on digital solutions for facilitating the transition towards a sustainable energy system. The center's research is conducted in close collaboration with industrial partners, public bodies, and government agencies. Dr. Jørgensen research focuses on digital solutions for integration of the demand-side with the supply-side in the energy sector, from the technology and business perspectives. He holds a Ph.D. in Computer Science from the University of Southern Denmark, a M.Sc. and a B.Sc. in Computer System Engineering from Odense University, Denmark

Practical information

Physical participation

24 August	Location for Day one	Green Tech House, Dandy business park (Lysholt Allé 10, 7100 Vejle, Denmark; see the map below)
24 August	Location for formal dinner	Hotel BEST WESTERN ToRVEhallerne (Address: Fiskergade 2-8, DK-7100 Vejle)
25 August	Location for Day two	Tent No.7, Green Zone of the Innovation Festival, Dandy business park (Address: Lysholt Allé 1-10, 7100 Vejle, Denmark; please see the map below)

Online participation

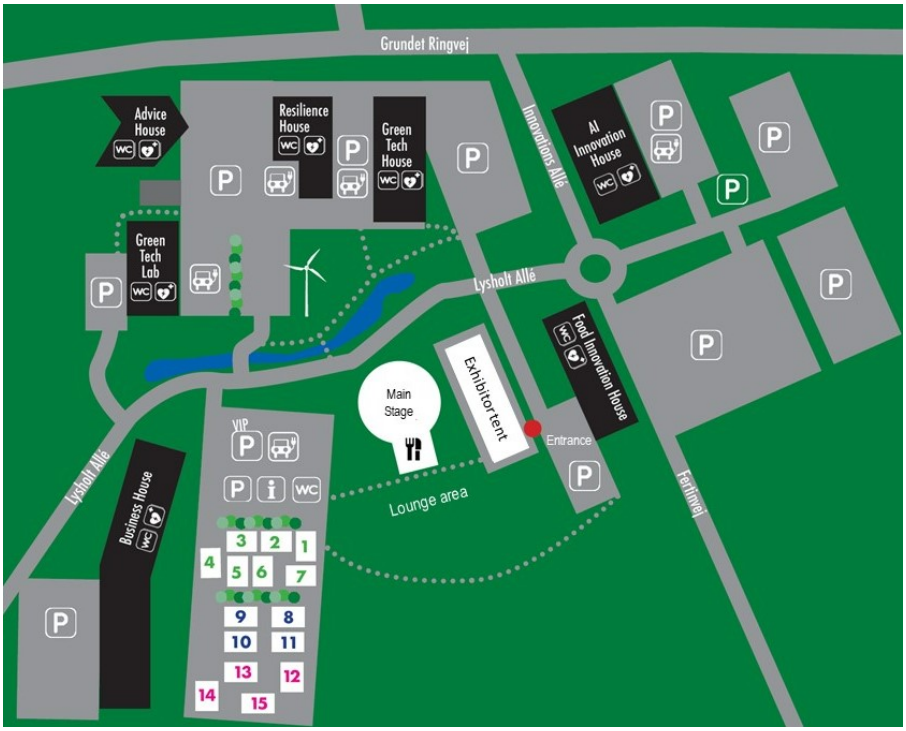
	Time (CET)		Zoom Link
24 August	09.00-9.20	Opening	https://syddanskuni.zoom.us/j/67756421308
	09.20-12.00	Paper presentation session for Theme of Simulation and modeling in energy	https://syddanskuni.zoom.us/j/67756421308
	09.20-12.00	Paper presentation session for Theme of Software and applications in energy	https://syddanskuni.zoom.us/j/64925455039
	13.00-16.00	Paper presentation session for Theme of Big data and AI in energy	https://syddanskuni.zoom.us/j/67756421308
	13.00-16.00	Paper presentation session for Theme of Energy informatics projects and analysis	https://syddanskuni.zoom.us/j/64925455039
25 August	09.00-16.30	Keynote speech & Panel session	https://syddanskuni.zoom.us/j/64002255125

Map of Green Tech house (24 August 2022)

Green Tech House | Address: Lysholt Allé 10, 7100 Vejle, Denmark

Map of Energy Informatics.Academy conference 25 August

Energy Informatics.Academy conference is in **Tent No.7**, **Green Zone**, at the Innovation festival (Address: Dandy business park, Lysholt Allé 1-10, 7100 Vejle, Denmark)



Contact Information

For any enquiry, please contact us by email: contact@energyinformatics.academy

For any emergency, please contact us by mobile phone:

Zheng Grace Ma: +45 2910 1947

Kristoffer Christensen +45 5117 3773