Book of Abstracts: 6th International Conference on Smart Energy Systems

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6TH INTERNATIONAL CONFERENCE ON SMART ENERGY SYSTEMS

6-7 October 2020

BOOK OF ABSTRACTS

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6th International Conference on Smart Energy Systems
6-7 October 2020

Book of Abstracts

Aalborg University
Department of Planning
Rendsburggade 14
9000 Aalborg

Editor-in-Chief: Henrik Lund

Frontpage photos: Peter Kristensen

Preface

It is a great pleasure to welcome you to the **6th International Conference on Smart Energy Systems** on 6-7 October 2020. The conference is organised by Aalborg University and Energy Cluster Denmark. The Conference is sponsored by Kamstrup, LOGSTOR, Grøn Energi, Ørsted and Aalborg Forsyning.

After last year's success in Copenhagen with 180 presentations and more than 300 participants, we are indeed happy to be able to welcome you to this year's conference in a new virtual setting. The 6th conference in the series cements it as a main venue for presenting subjects that are pertinent to the development and implementation of smart energy systems to fulfil national and international objectives. Once again, we welcome more than 200 participants from 20 countries around the world. We wish to thank everyone for your valuable contributions.

COVID 19 has affected lives, societies, working conditions and research throughout the world during the last nine months, and it has also affected this year's SES Conference. Due to the uncertainties caused by COVID 19, we early on adopted a robust hybrid approach by deciding to enable both physical and virtual attendance. In this decision-making process, we drew on experiences from other conferences such as the SDEWES conference series. We feel that both the topic of this conference and the conference as a venue for researchers in this field is too important to break tradition and postpone or even cancel. In the end, new COVID 19 regulations forced us to hold the conference exclusively as an online event. We thank all of you for your continuous support in uncertain times.

Similar to last year, the conference has a focus on smart energy systems, sustainable energy, electrification of the heat and transport sectors, electrofuels and energy efficiency. The aim of the conference is to establish a forum for presenting and discussing scientific findings and industrial experiences related to the subject of smart energy systems based on renewable energy, 4th Generation District Heating Technologies and Systems (4GDH), electrification of heating and transport sectors, electrofuels and energy efficiency.

The Smart Energy System concept is essential for 100% renewable energy systems to harvest storage synergies and exploit low-value heat sources. The most effective and least-cost solutions are to be found when the electricity sector is combined with the heating and cooling sectors and/or the transport sector. Moreover, the combination of electricity and gas infrastructures may play an important role in the design of future renewable energy systems.

All presentations, discussions, talks and debates during the conferences contribute to the understanding and development of future energy systems.

We wish you all a fruitful conference,

Henrik Lund, Brian Vad Mathiesen, Poul Alberg Østergaard and Hans Jørgen Brodersen
Conference organisers, Aalborg University and Energy Cluster Denmark

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Call for abstracts

The Smart Energy System concept is essential for cost-effective 100% renewable energy systems. The concept includes a focus on energy efficiency, end use savings and sector integration to establish energy system flexibility, harvest synergies by using all infrastructures, lower energy storage cost as well as to exploit low value heat sources.

As opposed to, for instance, the smart grid concept, which takes a sole focus on the electricity sector, the smart energy systems approach includes the entire energy system in its identification of suitable energy infrastructure designs and operation strategies. Focusing solely on the smart electricity grid often leads to the definition of transmission lines, flexible electricity demands, and electricity storage as the primary means of dealing with the integration of fluctuating renewable sources. However, these measures are neither very effective nor cost-efficient considering the nature of wind power and similar sources. The most effective and least-costly solutions are to be found when the electricity sector is combined with the heating and cooling sectors and/or the transport sector. Moreover, the combination of electricity and gas infrastructures may play an important role in the design of future renewable energy systems, and the electrification of heating and transport – possibly through electrofuels – can play a pivotal role in providing flexibility and ensuring renewable energy integration in all sectors.

In future energy systems, energy savings and 4th generation district heating can be combined, creating significant benefits. Low-temperature district heat sources, renewable energy heat sources combined with heat savings represent a promising pathway as opposed to individual heating solutions and passive or energy+ buildings in urban areas. Electrification in combination with district heat is a very important driver to eliminate fossil fuels. Power heat, power to gas and power to liquid together with energy efficiency and 4th generation district heating create a flexible smart energy system. These changes towards integrated smart energy systems and 4th generation district heating also require institutional and organisational changes that address the implementation of new technologies and enable new markets to provide feasible solutions to society.

We invite researchers and experts from industry and business to contribute to further enhancing the knowledge of smart energy systems, 4th generation district heating, electricfication, electrofuels and energy efficiency.

Important Dates 2020

2 June	Deadline for submission of abstracts (**NB** Additional upgrade to paper is optional)
8 June	Reply on acceptance of abstracts
30 June	Early registration deadline
13 Sep	Normal registration deadline
6-7 Oct	Conference

Topics

Smart energy system analyses, tools and methodologies

Smart energy infrastructure and storage options

Integrated energy systems and smart grids

Institutional and organisational change for smart energy systems and radical technological change

Energy savings, in the electricity sector, in buildings and transport as well as within industry

4th generation district heating concepts, future district heating production and systems

Electrification of transport, heating and industry

The production, technologies for and use of electrofuels in future energy systems

Planning and organisational challenges for smart energy systems and district heating

Geographical information systems (GIS) for energy systems, heat planning and district heating

Components and systems for district heating, energy efficiency, electrification and electrofuels

Renewable energy sources and waste heat sources for district heating

Fee including materials, coffee, lunches:

- Early registration (for presenters with accepted abstracts): **300 EUR** (attending in Aalborg) / **200 EUR** (virtual attendance)
- Normal fee: **400 EUR** (attending in Aalborg) / **300 EUR** (virtual attendance)
- Additional fee for conference dinner: **100 EUR**

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Aim and Organisers

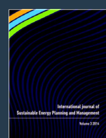
The aim of the conference is to establish a venue for presenting and discussing scientific findings and industrial experiences related to the subject of Smart Energy Systems based on renewable energy, 4th Generation District Heating Technologies and Systems (4GDH), electrification of heating and transport sectors, electro fuels and energy efficiency. This 6th conference in the series cements it as a main venue for presentations and fruitful debates on subjects that are pertinent to the development and implementation of smart energy systems to fulfil national and international objectives.

The conference is organised by Aalborg University and CLEAN with support from the RE-INVEST and the sEEnergies projects.

- RE-INVEST is an international research project, which develops robust and cost-effective renewable energy investment strategies for Denmark and Europe funded by Innovation Fund Denmark.
- sEEnergies is a European research project focusing on Smart Energy Systems and supply chain effects on energy efficiency in all sectors and infrastructure funded by Horizon 2020.

Submission Procedure

Both scientific and industrial contributions to the conference are most welcome. Submitted abstracts will be reviewed by a scientific and an industrial committee. Authors of approved abstracts will be invited to submit papers to special issues of Energy, IJSEPM and Energies. Abstracts may be presented at the conference without uploading full paper, as this is not a requirement.



Best Presentation Awards will be given to a selected number of presenters at the conference.

Abstracts can be submitted via **www.smartenergysystems.eu** from 27 January to 2 June 2020.

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International Scientific Committee

Prof. Dagnija Blumberga, Riga Technical University, Latvia
Dr. Robin Wiltshire, Building Research Establishment (BRE), UK
Dr. Anton Ianakiev, Nottingham Trent University
Dr. Ralf-Roman Schmidt, Austrian Institute of Technology, Austria
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LIVE SESSIONS

Tuesday 6 October at 09:00-11:30	LIVE SESSION
09:00-11:30	**1st plenary session chaired by Professor Poul Alberg Østergaard**
09:00-09:15	**Professor Henrik Lund**: Opening speech
09:15-10:00	**Mogens Lykketoft, former president of the UN General Assembly**: On track towards a sustainable future?
10:00-10:15	Short break
10:15-10:45	**Catharina Sikow-Magny, Director of the EC Directorate General for Energy**: EC Strategy on Energy System Integration
10:45-11:30	**Michael Lundgaard Thomsen, Managing Director at Aalborg Portland:** Roadmap for sustainable cement production in Denmark

Wednesday 7 October at 13:15-15:15	LIVE SESSION
13:15-15:15	**2nd plenary session chaired by Professor Brian Vad Mathiesen**
13:15-13:45	**Soteris Kalogirou, Professor at Cyprus University of Technology:** Renewable Energy Systems - Current status and Prospects In the World
13:45-14:15	**Lauren Edelman, Energy Specialist at Facebook:** Facebook's commitment to renewable energy and energy efficiency: Innovation and Heat Recovery
14:15-14:45	Panel debate
14:45-15:00	Best Presentation Award ceremony
15:00-15:15	**Professor Henrik Lund**: Closing speech

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Smart energy system analyses, tools and methodologies

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Andra Blumberga: Achieving Positive Energy Block in historic urban environment: simulation and evaluation of alternative scenarios

Stef Boesten: Water to water heat pump for district heating: modeling for MILP optimization and application to a real case study

Hermann Edtmayer: Sector Coupling Potentials of a 5th Generation District Heating and Cooling Network

Thomas Estermann/Elisabeth Springmann: Method for determining the feasibility of Grid and Ancillary Services by Smart Meters

Luca Ferrari: Integrated planning of multi-energy systems (PlaMES): comprehensive modelling framework and decision support tool

Matteo Giacomo Prina: Optimization method to obtain marginal abatement cost-curve through EnergyPLAN software

Hans Christian Gils: The Contribution of Flexible Sector Coupling to Fully Renewable Electricity Generation in Australia

Elisa Guelpa: Maximize the effects of district heating demand response in multi-energy optimization

Marnoch Hamilton-Jones: Fault detection and optimization potential on the demand side of district heating systems

Aleksandar Ivancic: Evaluation of district energy systems with shared systems for heating and cooling generation

Joseph Jebamalai: An Automated Method to Design Multi-Source District Heating Networks with Integrated Thermal Energy Storage – A Case Study

Hicham Johra: Using data from smart energy meters to gain knowledge about building clusters connected to district heating networks: A Danish example

Goran Krajačić: Modelling the water-energy nexus of the future smart island

Shravan Kumar: Comparison of modelling approaches for operational optimization of district cooling networks

Ari Laitala: Modelling one hour level heating energy consumption of buildings – can AI algorithms enhance the understanding?

Thomas Licklederer: A Thermohydraulic Model of Bidirectional Heat Networks with Prosumers

Danica Maljkovic: Evaluation of energy efficiency measures in district heating systems with deep learning

David Maya-Drysdale: How scenarios can facilitate local energy planning in cities

Andrea Menapace: A flexible methodology to analyse 100 % renewable energy cities

Steffen Petersen: Evaluating the temperature performance of Danish building typologies in district heating networks

Uni Reinert Petersen: Pathways towards 100% renewable energy on the Faroe Islands

Stefan Petrović: An improved modelling of Danish district heating supply and demand in the future energy system

Marianna Pozzi: A transparent assessment of retrofit potential in Italy based on open data

Diego Viesi: A cost-optimized approach in regional decarbonisation: the integrated and dynamic energy modelling of the Province of Trento

Fan Zhang: Night Setback Identification of District Heat Substations using Bidirectional Long Short Term Memory with Attention Mechanism

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4th Generation District Heating concepts, future district heating production and systems

Theofanis Benakopoulos: Faults detection and low operating temperatures in radiator system by using data from existing digital heat cost allocators in a multi-family building

Tom Burton: Techno-economic assessment of external HIU cupboards on low temperature heat networks

Michel Gross: Model based analysis of future district heating networks

Oddgeir Gudmundsson: Central heat plant vs decentral temperature boosting in district heating

Mengting Jiang: A data-driven approach for fast and accurate dynamic simulation of district heating networks

Gareth Jones: Acceptance Testing: Improvement of network performance through standardised dwelling test regime

Mathias Kersten: Emission reduction in 4th generation district heat supply networks

Igor Krupenski: District cooling system operation in cold climates with existing district heating networks

Ingo Leusbrock: DESTOSIMKAFE – Development & rating of technical & organizational system solutions for cold DH to supply heating and cooling

Graeme Maidment: Exploring 5th Generation Integrated energy systems

Sara Månsson: A taxonomy for labelling deviations in district heating systems

Thomas Naughton: Process for optimising heat network performance of existing buildings in the UK

Ivo Pothof: Robust thermo-hydraulic design of prosumer district heating networks

Pavel Ruševljuk: Economic Dispatch of District Heating Networks via Consumption-Based Management

Costanza Saletti: Enabling smart control by optimal management of the State of Charge of district heating networks

Amos Schledorn: An advanced optimization -based bidding method for district heating providers considering uncertainty and block bids

Tim Taylor: Case study of a 3rd gen CHP district heating system that got updated to a 5th gen system with a shared ground source heat pump system

Jan Eric Thorsen: Experience with booster for DHW circulation in multi apartment building

Riccardo Toffanin: Impact of Legionella regulation on a 4th generation district heating substation energy use and cost: the case of a Swiss single-family household

Ulrich Trabert: Feasibility study and techno-economic evaluation of a DH integration of a river water heat pump at a CHP plant in Germany

Anna Vannahme: Comparison of Different District Heating Substation-Systems in a Hardware-in-the-Loop-Test Rig

Yannick Wack: Showcasing the potential of adjoint-based topology methods to optimize District Heating Network design on district level

Sven Werner: Vocabulary for fourth generation of district heating

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Components and systems for DH, energy efficiency, electrification and electrofuels

Louise Christensen: Thermal comfort and technology acceptance in homes with demand -responsive control of radiator thermostats

Yuriy Lobunets: Regenerative Thermoelectric Heat Pump for HVAC Systems

Dmitry Romanov: Technical, economic and ecological effects of lowering temperatures in the Moscow district heating system

Pierre JC Vogler-Finck: Field experience of data-driven control and monitoring to support energy efficient and flexible building operation

Benjamin Zühlsdorf: Model-based fault detection for use in digital twins of large-scale heat pump systems

Planning and organisational challenges for smart energy systems and district heating

Dagnija Blumberga: How to start the waste heat and boiler house competition in Latvia

Saeid Charani Shandiz: Towards net-zero emission and energy resilient communities: a multi-dimensional approach to energy master planning

Hrvoje Dorotić: Cost and Benefits of Shifting Towards Low Temperature District Heating Networks – Energy Planning Approach

Leire Gorroño-Albizu: How could heat consumers' trust in district heating solutions be enhanced? Insights from Denmark and Sweden

Britta Kleinertz: District heating supply transformation –Strategies, measures and status quo of network operators transformation phase

Louise Krog: 4th generation district heating, consumers, consumer involvement

Stefano Morgione: A comprehensive framework for District Energy Systems Upgrade

Matteo Pozzi: Supporting Electricity Trading towards XBID implementation through innovative District Energy plant management

Tars Verschelde: Case studies on a decision support tool for thermal networks

Electrification of transport, heating and industry

Amela Ajanovic: Impact of coronavirus crisis on electrification of mobility

Nina Detlefsen: How electrification of the heating and transportation sector affects the load in low voltage electricity grids

Christine Gschwendtner: Uncertain impacts of technology, infrastructure, and vehicle use types on the integration of Vehicle-to-grid (V2G) into distribution networks

Reinhard Haas: The correlation between variable renewable energy sources and energy demand for heating&cooling

Sajjad Haider: Uncontrolled Electric Vehicle Charging in Low Voltage Grids – Impacts

Simon Meunier: Towards mapping grid reinforcement costs from residential low-carbon technologies penetration in Europe

Adrian Ostermann: Potential of vehicle to grid charging control of electric vehicles in congestion management

Niklas Wulff: Vehicle Energy Consumption in Python (VencoPy): Presenting and demonstrating an open source tool to calculate electric vehicle charging flexibility

Meng Yuan: The role of transportation electrification in the energy transformation of urban agglomerations: A case study of Beijing-Tianjin-Hebei region

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Smart energy infrastructure and storage options

Diederik Coppitters: Epistemic and aleatory uncertainty quantification of a grid-connected photovoltaic system with battery storage and hydrogen storage

Christine Damgaard Asmussen: Optimizing a grid-connected household photovoltaic installation in Denmark

Steven Dijkstra-Downie: Energy Strategy for Expanding Scottish Towns Greenspaces, waterbodies, shared ambient loops, heat pumps and PV to heat and power town growth projects

Julian Formhals: Dynamic transition to a renewable and efficient campus solar district heating grid with integrated medium deep borehole thermal energy storage

Luka Herc: Economic viability of flexibility options for smart energy systems with high share of renewable energy

Martin Heine Kristensen: Heat load demand response experiment in social housing apartments using wireless radiator setpoint control

Poul E. Kristensen: Wind + sun for 100% RE heating of buildings

Kertu Lepiksaar: Increasing CHP flexibility to improve energy system efficiency

Rasmus Lund: Combined heat and power storage: Feasibility in a national renewable energy system context

Johannes Röder: Decentral Heat Storages in System-Beneficial District Heating Systems – an Integrated Optimization Approach

Ligang Wang: Converting wastes efficiently and flexibly for grid-balancing services and sector coupling

Institutional and organisational change for smart energy systems and radical technological change

Gatis Bazbauers: Linking energy efficiency policies toward 4th generation district heating system

Andrej Guminski: Holistic evaluation scheme for industrial greenhouse gas abatement measures – bringing together research and practice

Andreas Müller: How much to invest? Balancing investment costs and economic benefits of reducing the temperature levels in existing district heating networks

Robert Pratter: HEATflex: Development of a common technical & economic strategy to increase the competitiveness of CHP & district heating plants

Callum Rae: Practical learnings from deployed Smart Local Energy Systems: technical barriers to scale-up

Leon Joachim Schwenk-Nebbe: CO2 quota attribution effects on the European electricity system

Daniel Møller Sneum: Flexibility in the interface between district energy and the electricity system

Karl Vilén: The Impact of Climate Policy on the District Heating System in a Nordic city

Behnam Zakeri: Aftermath of COVID19 and the Energy Sector: Is a green recovery from economic slowdown possible?

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Energy savings in the electricity sector, buildings, transport and industry

Debmalya Biswas: Reinforcement Learning based HVAC Optimization in Factories

Henrik Brink: Identifying optimisation potential in electricity consumption profiles from hourly smart meter data at scale

Daniel Heidenthaler: Thermally activated building systems in wooden structures

Marcus Hummel:
Using least cost renovation combinations in buildings for developing future heat demand density maps: case studies in three cities in Europe

Paolo Leoni: Lowering the operating temperatures in old-generation district heating systems: first results from the TEMPO demonstration project in Brescia (Italy)

Antoine Levesque: Decarbonising buildings energy services through demand and supply

Chiara Piccardo: Life cycle cost and primary energy analysis of a multi-storey residential building retrofit to different energy levels with varied materials

Sverre Stefanussen Foslie: Integrated heating and cooling in the industry through heat pumps and thermal energy storages – case study of an electrified dairy

Dimitra Tzani: Different portfolios of measures to improve efficiency in the residential sector in Greece towards the achievement of the 2030 targets

The production, technologies for and use of electrofuels in future energy systems

Christian Bundgaard: System Effects of Implementing Electrofuels for Decarbonisation of the Transport Sector in a Danish Perspective

Tobias Hübner: Simulation-based analysis of synthetic fuels in the industry in relation to climate protection level

René Kofler: Comparison of different biorefinery systems integrating the electricity, heating and transport sector

Xavier Rixhon: The role of electro-energy carriers under uncertainties for Belgian energy transition

Hammam Soliman: Contribution of Power-to-X-to Power in retrofitting of Coal-Fired Power Plants

Christian Thommessen: Techno-economic System Analysis of an Offshore Energy Hub and Outlook of Electrofuel Applications

Kevin Verleysen: Influence of parametric and operational uncertainties on the dynamic operation of the Haber-Bosch synthesis process for seasonal hydrogen storage

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Integrated energy systems and smart grids

Hamza Abid: Energy storage integration with solar PV for increased electricity access: A case study of Burkina Faso

Matthias Greiml: Assessing usage of power-to-gas as an alternative to electricity grid expansion to increase photovoltaic generation in south-east Austria

Bastian Hase: Using Short-Time Storage Potentials of Run-of-River Hydroelectric Plants for Frequency Control

Gauthier Limpens: Intermittent renewable energy integration: assessing the benefits of the flexibility options

Pia Manz: Future synergies of industrial excess heat potentials and buildings energy demand in Germany

Torben Ommen: Economic feasibility of fuel-shift appliances supplied by gas, electricity and district heating in Denmark

Frederik Palshøj Bigum: Real-scale integrated renewable energy systems

Dietrich Schmidt: Digitalisation of district heating systems

Vittorio Verda: Challenges in adoption of district cooling in densely populated areas

Marta Victoria: Early decarbonisation of the European energy system pays off

Geographical Information Systems (GIS) for energy systems, heat planning and district heating

Alice Dénarié: Assessment of renewable and waste heat recovery in DH through GIS mapping: the national potential in Italy

Mostafa Fallahnejad: District Heating Grid Planning

Fabrizio Fattori: A Regression Model to Estimate the Dwelling-Network Connection Length Starting from Aggregated Information per Census Area

Markus Groissböck: Energy hub optimization framework based on open-source (software & data) – Review of frameworks and concept for districts & industrial complexes

Morten Karstoft Rasmussen: Data driven asset management – online distribution grid analysis based on GIS and meter consumption data

Nina Kicherer: Design of a District Heating Roadmap for Hamburg

Hannes Koch: Rooftop photovoltaic - an algorithmic solution for obtaining total potential power generation by processing solar irradiance data

Samuel Macchi: A validated method to simulate district heating network topologies to enable assessing district heating cost

Johannes Pelda: FERNWÄRMEATLAS – An Online Tool to Collect Information about District Heating Systems in Germany

Abdulraheem Salaymeh: Determination of the district heating supply structure based on geospatial and statistical data

Martin Santa Maria: District heating system optimization with RIVUS, Case study Salzburg

David Schmidinger: Assessment of future heat demand and supply with the HOTMAPS toolbox: A case study for San Sebastian

Giulia Spirito: Potential diffusion of renewable based 3GDH and 4GDH assessment through energy mapping: a case study in Milano

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Special session on Innovating SMEs

Hans Jørgen Brodersen: Turning SME ideas into New Smart Energy Solutions

Bo Eskerod Madsen: Clamp-on Monitoring of Energy from the Outside of Existing Multiconductor Cables and Pipes

Bjarke Henriksen: Total Building Automatic Energy Management

Mario Javier Rincón: Micro-ORC Technology Development

Henning Schmidt-Petersen: Biomass treatment - How to turn a problem into a resource

Renewable energy sources and waste heat sources for district heating

Lina Aglén: Potential of unutilised waste-heat possible to incorporate into UK district heating production

Lisa Altieri: Selecting the right heat source in an ultra-low temperature heating network

Helge Averfalk: Low-temperature excess heat recovery in district heating systems: The potential of European Union metro stations

Federico Bava: Feasibility analysis of renewable DHC concepts in different climatic zones

Roman Geyer: Implementation of low-temperature district heating and its benefits

Stefan Holler: Feasibility study on solar thermal process heat in the beverage industry

Anna Kallert: A Showcase Project: 4th Generation District Heating in Moosburg an der Isar

Hironao Matsubara: Heat Roadmap Japan: Smart energy system combining renewable energy and district energy to decarbonize urban area in Japan

Wiebke Meesenburg: Flexible heat supply from supermarket refrigeration systems

Francesco Mezzera: District heating potential in a hydrogen-based energy system - An exploratory focus on Italy

Peter North: A pathway towards the heat autonomous city

Henrik Pieper: Ranking of heat sources and sinks based on seasonal performance estimation and demands for heating and cooling areas

Tobias Reiners: Waste heat from mine water in an ultra low temperature district heating network

Akos Revesz: Waste heat integration into heat networks; a UK wide assessment

Brage Rugstad Knudsen: Demand-side management for reducing peak-heating costs in a local low-temperature district heating grid with waste-heat utilization

Dirk Vanhoudt: TEMPO - Results of the first temperature reduction measures in the demo sites

Jelena Ziemele: A multi-factorial decision support tool for integration of small-scale industrial heat pumps and solar PVs into a district heating system

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Best Presentation Award is donated by Kamstrup

The researchers making presentations at this year's International conference on Smart Energy Systems will be competing for the Best Presentation Award—one of which is sponsored by Kamstrup. Kamstrup will be donating the Best Presentation Award worth 1000 euro to a presenter with excellent communication skills.

Last year, Kamstrup sponsored the Best Senior Presentation Award. Professor and Centre Leader at DTU Compute, Henrik Madsen, was awarded for the presentation ”Perspectives in Using Meter Data for Temperature Optimization”. The nomination was justified by his enthusiasm and passion and because he keeps pushing the boundaries of control methods.

Kamstrup is a world-leading supplier of intelligent energy and water metering solutions, so Henrik Madsen’s presentation resonated with the company’s interest.

“Henrik’s presentation was an excellent example on the potential for increased digitalization in the DH industry. Temperature optimization based on real time data from smart meters makes it possible to operate the network closer to the limits and is thus a key enabler to lower the temperature levels in a DH system. And lower temperatures is a necessity for integrating large amounts of waste heat and renewable energy in the system,” says Steen Schelle Jensen, Head of Business Development, Heat/Cooling at Kamstrup.

In 2019, Henrik Madsen was happy to receive his award for Best Senior Presentation sponsored by Kamstrup. Photo: DTU Compute


Let's create a world that runs entirely on green energy
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Aalborg Forsyning - silver sponsor of this year’s conference

Aalborg Forsyning provides District Energy solutions for the city of Aalborg and its surrounding area. This with a high reliability and at cost genuine terms.

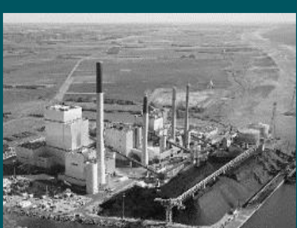
Today, we supply our customers with district heating and gas. From 2021 we will also be able to supply our customers with district cooling.

Our aim is to continuously minimize the energy consumption and to have a 100 % renewable, diversified energy system within the next decade.

Aalborg Forsyning, Energi has four main activities:

- We ***produce*** district heating, cooling and electricity.
- We **sell** district heating, gas, cooling and electricity.
- We **distribute** district heating, cooling and gas.
- We offer **services and solutions** to minimize the energy consumption for both private and public customers and the industry.

Aalborg Forsyning



www.aalborgforsyning.dk

Best Presentation Award Winners of previous conferences

Best PhD Presentation:

2019: Maria Jangsten, Chalmers University of Technology

2018: Britta Kleinertz, Research Center for Energy Economics

2017: Kanau Takahashi, Kyoto University

2016: Magnus Dahl, Aarhus University/AffaldVarme Aarhus

2015: Dorte Skaarup Larsen, Technical University of Denmark

Best Senior Presentation:

2019: Henrik Madsen, Technical University of Denmark

2018: Benedetto Nastasi, TU Delft

2017: Svend Svendsen, Technical University of Denmark

2016: Martin Crane, Carbon Alternatives Ltd

2015: Urban Persson, Halmstad University

Conference Chairs

Henrik Lund, Professor in Energy Planning at Aalborg University, Denmark

Professor Henrik Lund is Editor-in-Chief of Elsevier's international journal ENERGY and a world leading scientist. He is ranked among the top 1% researchers on the world on the Thomson Reuter's list of highly cited researchers. He holds a PhD in "Implementation of sustainable energy systems" (1990) and a senior doctoral degree in "Choice Awareness and Renewable Energy Systems" (2009). Henrik Lund has more than 30 years of research experience and involvement in Danish energy planning and policy-making. Among others, he has been involved in the making of the Danish Society of Engineers' proposal for a future 100% Renewable Energy Plan for Denmark. He has headed several large research projects in Denmark and Europe. Henrik Lund is the main developer of the advanced energy system analysis software EnergyPLAN, which has several thousand registered users around the world. Henrik Lund has contributed to more than 400 books and articles.

Brian Vad Mathiesen, Professor in Energy Planning at Aalborg University, Denmark

Brian Vad Mathiesen, Professor in Energy Planning and Renewable Energy Systems at Aalborg University, holds a PhD in "Fuel cells and electrolysers in future energy systems" (2008). His research focuses on technological and socioeconomic transitions to renewables, energy storage, large-scale renewable energy integration and the design of 100% renewable energy systems. He is one of the leading researchers behind the concepts of Smart Energy Systems and electrofuels. He has published 200 scientific articles and reports and is on the Clarivate Web of Science List of Highly Cited Researchers (2015-2020), thus among the top 1% most cited researchers globally. Among other positions, Brian Vad Mathiesen is a member of the EU Commission expert group on electricity interconnection targets in the EU and the newly founded Science Advice for Policy by European Academies (SAPEA) Expert Group on A Systemic Approach For the Energy Transition In Europe. He is the Research Coordinator of the Sustainable Energy Planning Research group and Programme Director for the MSc in Sustainable Cities at Aalborg University. He is the Principal Investigator (PI) of the RE-INVEST and sEEnergies projects and has been PI, work package leader and participant in more than 60 research projects. Furthermore, he is an editorial board member of The Journal of Energy Storage (Elsevier) and The Journal of Sustainable Development of Energy, Water &

Environment Systems; Associate Editor of Energy, Ecology and Environment (Springer) and Editor of the International Journal of Sustainable Energy Planning and Management. Recently he started the new Elsevier Journal Smart Energy. In addition, he is a member of The Danish Academy of Technical Sciences (ATV) and a board member at The Danish Energy Technology Development and Demonstration Programme (EUDP).

Poul Alberg Østergaard, Professor in Energy Planning at Aalborg University, Denmark

Poul Alberg Østergaard is Professor in Energy Planning at Aalborg University. He holds a PhD in "Integrated Resource Planning" (2000) and has more than 20 years of research and teaching experience within Energy Planning. Poul A. Østergaard's research competences include analysis of energy systems with large-scale integration of fluctuating renewable energy sources; optimisation criteria of energy systems analyses, and sustainable energy scenarios for local areas. Poul A. Østergaard has led and been involved in many research projects all focusing on renewable energy scenarios, integration of renewable energy sources into the energy system and framework conditions for renewable energy scenarios. He has authored/co-authored more than 100 scientific papers in highly reputed publications and is the editor-in-chief of the International Journal of Sustainable Energy Planning and Management. Furthermore, Poul A. Østergaard is the Programme Coordinator and a distinguished teacher of the M.Sc. programme in Sustainable Energy Planning & Management at Aalborg University.

RE-INVEST is a four-year research project gathering 17 partners from universities and key energy players in a unique approach to the complete redesign of the entire energy system, utilizing the synergies between heat, electricity and transport.

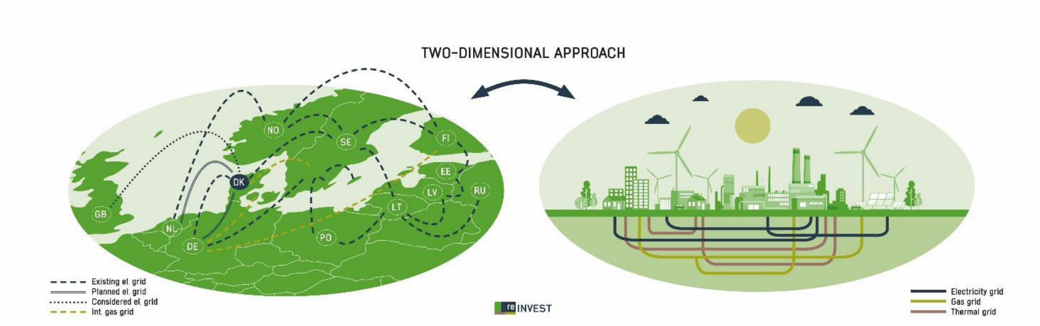
RE-INVEST aims at designing robust and cost-effective investment strategies that will facilitate an efficient transformation towards a sustainable or 100% renewable energy system in Denmark and Europe.

RE-INVEST addresses how to overcome the silo thinking that characterizes traditional energy sectors, by using a two-dimensional interconnectivity approach as well as existing and new energy infrastructures. The aims are:

1. To develop the Smart Energy System concept and identify synergies in low-cost energy storages across sectors as well as energy savings on the one side, and international electricity and gas transmission on the other side, when expanding e.g. wind power;

2. To support stakeholders within renewable energy in Denmark and Europe and enable the industrial partners in the project to be early adopters of trends in integrated energy markets, thus having cutting edge R&D for key technologies in future sustainable energy systems;

3. To share data, results, models and methodologies on open platforms and be open to new partnerships.



Read more about RE-INVEST at www.reinvestproject.eu sEEnergies is a European research project focusing on Smart Energy Systems and supply chain effects on energy efficiency in all sectors and infrastructure. The project is funded by EC Horizon 2020, Grant Agreement no. 846463. sEEnergies has a duration of 2½ years and gathers 9 partners from universities and key energy players in Europe.

sEEnergies goes beyond state-of-the-art science-based knowledge and methods, as it combines sectorial bottom-up knowledge with hour-by-hour modelling of the energy systems and spatial analysis in the EU.

The project develops a holistic temporal and spatial assessment of energy efficiency potentials by utilising energy system synergies and in this way make energy efficiency more operational as a first principle.

sEEnergies assesses the energy-related impact of the first principle of energy efficiency at the sector and energy system levels to quantify energy efficiency and make it comparable with investments on the supply side. It also assesses the additional impact of energy efficiency measures in different sectors, as well as their impact on markets in order to support policies aiming at promoting and implementing energy efficiency as a first principle.

Furthermore, sEEnergies develops an online GIS visualisation platform to make the first principle of energy efficiency more concrete in relation to energy demand and supply.

Read more about sEEnergies at www.seenergies.eu

Plenary Keynote Speakers

Mogens Lykketoft was President of the United Nations General Assembly in 2015-2016, when the Sustainable Development Goals and the Paris Climate Agreement were adopted. Since then, he has devoted most of his time – during over 350 meetings in Denmark and abroad and in lots of articles and TV presentations – to inform about the Global Goals and agitate for the urgency of Climate Action. He is an Economist from the University of Copenhagen. During 38 years, he was elected to the Parliament of Denmark and, over the years, he served as Minister for Taxation, Finance and Foreign Affairs; Leader of the Social Democratic Party and Speaker of Parliament.

Michael Lundgaard Thomsen is Managing Director in Aalborg Portland A/S, which is the only cement producer in Denmark. He holds a MSc in Manufacturing Management and Systems combined with a HD – Business degree in Organisation and Innovation and an Executive MBA in Change Management and has more than 20 years' experience within top management. Prior to Aalborg Portland, Michael Lundgaard has held executive management positions as CEO and COO in companies like Danfoss, Siemens and Linak. In November 2019, he was appointed chairman in the climate partnership for energy intensive industry by the Danish Government. Furthermore, Michael Lundgaard Thomsen is member of the boards in the Confederation of Danish Industry (DI): Committee for Energy and Climate Policy, and Processing Industry Committee.

Plenary Keynote Speakers

Catharina Sikow-Magny joined the European Commission in 1997 and is the Director responsible for Internal Energy Market and the Head of Unit in charge of retail markets, coal and oil in the Directorate General for Energy. Before that, she was the Head of Unit in charge of networks and regional initiatives. She has as well worked on international transport, trans-European network policy and financing, internalisation of external costs, and strategic policy research. Before joining the Commission, Catharina Sikow-Magny was a team leader and chief economist in the private sector in Finland. She has also worked for the United Nations Development Programme in Port-au-Prince, Haiti. She holds a Master of Economics degree from the Aalto University, Finland.

Soteris Kalogirou is professor at the Department of Mechanical Engineering and Materials Sciences and Engineering of the Cyprus University of Technology and Editor-in-Chief of the Renewable Energy journal. For more than 35 years, Professor Soteris Kalogirou has been actively involved in research in the area of solar energy and particularly in flat plate and concentrating collectors, solar water heating, solar steam generating systems, desalination and absorption cooling. Additionally, he is involved in a pioneering research dealing with the building integration of solar thermal systems (BISTS), for which he chaired COST Action TU1205. He has been a member of World Renewable Energy Network (WREN) since 1992 and is a member of the American Society of Heating Refrigeration and Air-conditioning Engineers (ASHRAE), Institute of Refrigeration (IoR) and International Solar Energy Society (ISES).

Plenary Keynote Speakers

Lauren Edelman is an Energy Specialist at Facebook. Lauren Edelman's responsibilities include identifying and implementing energy efficiency and renewable energy solutions for Facebook's data centers. She has been a key contributor to Facebook's innovation in the energy space. Lauren Edelman supports Facebook's European data centre portfolio which includes facilities in Denmark, Sweden, and Ireland. In Odense, Denmark, she has led the implementation of the world's first large-scale heat recovery project from a hyperscale data center. Lauren Edelman joined Facebook in 2016, after working in project finance at SunEdison, a large renewable energy developer. She holds a BSE in Chemical and Biological Engineering from Princeton University.

Plenary keynote: Mogens Lykketoft

Mogens Lykketoft
Former President of the United Nations General Assembly

On track towards a sustainable future?

Five years ago, the United Nations agreed on two major decisions: The 17 global goals for sustainable development were approved by all 193 member countries. On Goal 13 – the Climate – in Paris, every single government agreed on the most ambitious plan of action to date.
Obviously, urgent climate action the number one necessary condition if our children and grandchildren are to live in a sustainable future.
However, we are not at all on track.
Both the United States and Brazil have stepped back, and all too many countries have not moved/are not moving sufficiently forward.
But awareness about the existential threats to future generations has increased tremendously in these same past five years. Mayors from the world's major cities and many large companies are in the forefront – as is an ever more active civil society with strong and powerful participation from the young generation.
Climate action is about terminating all use of fossil fuels on this planet well before 2050 – notwithstanding how much we have found or may find. This takes incredible political determination and public understanding all around the globe: We get most of our energy from fossil fuels today - and in order to supply all villages in India and Africa with the energy they need must be produced by a much cheaper and much more efficient use of renewables.
All this will take massive further development in technology and economies of a scale we cannot even image today. And it will only happen if governments change the regulatory framework of the markets by heavily taxing CO^2 emissions while supporting and encouraging sustainable companies – including cooperation in research and development between national and local governments, private companies, pension funds and other financial institutions.

Plenary keynote: Michael Lundgaard Thomsen

Michael Lundgaard Thomsen
Aalborg Portland

Roadmap for sustainable cement production in Denmark

Climate ambitions in Denmark with a 70% reduction target in 2030 and in EU with a CO2-neutral target in 2050 are accelerating the green transition of the cement industry.
The cement industry is one of the hard to abate sectors due to the energy intensive production (40- 50% of the scope 1 emissions) and the mineralogical process-emissions from the limestone (50-60% of the scope 1 emissions).
Ontheonehand,thecementindustryaccountsongloballevelforupto8%oftheCO2-emissions,but on the other hand, the cement industry produces an indispensable product for the construction sector.
Due to the growing urbanisation, establishing of green energy facilities and climate protection the need for cement is estimated to double in 2025. Therefore, a green transition of the cement industry is mandatory andunavoidable.
At Aalborg Portland, the CO2-reduction target for 2030 is 30% with existing technologies and policies but going further towards a 70% or 100% CO2-reduction can potentially be possible with the right policies, subsidies, energy sources and technologies. In short, a reduction beyond 30% is closely dependent on externalfactors.
Director of the Aalborg Portland cement plant, Michael Lundgaard Thomsen, will present the 2030 roadmap for cement production in Denmark and will also give insight about the Climate Partnership for Energy Intensive Industry, which was established by the Danish government with the aim of counselling the government on climate policies.

Plenary keynote: Catharina Sikow-Magny

Catharina Sikow-Magny

EC Strategy on Energy System Integration

The Commission has adopted on 8 July a Strategy on “Energy system integration”. Energy is responsible for 75% of greenhouse gas emissions. If we want to achieve climate-neutrality, we need to fully rethink our energy system.
Today’s energy system is still built on several parallel, vertical energy value chains. For instance, oil is mainly used to drive our cars, or gas is used to heat our homes. This model of separate silos cannot deliver a climate-neutral economy. It is technically and economically inefficient, and leads to substantial losses in the form of waste heat and low energy efficiency.
Energy system integration, in contrast, is the coordinated planning and operation of the energy system ‘as a whole’, across multiple energy carriers, infrastructures, and consumption sectors. Only this approach can deliver an effective, affordable and deep decarbonisation of the European economy. System integration will also contribute to job and growth creation, security of supply, and global industrial leadership. System integration also provides numerous opportunities for short term investments in the post-Covid recovery context.
The Strategy adopted by the Commission sets out a vision on how to accelerate the transition towards a more integrated energy system in Europe. It will guide the reforms of the European energy system in the next few years.
The strategy relies on three pillars.
First, create a more circular energy system, with “energy-efficiency-first” at its core: Too much energy or potential energy is wasted in our current system, from heat and gases that are released into the atmosphere, to by-products of industrial processes and energy production, which could be captured and used for other purposes.
Second, to accelerate electrification, based on a largely renewables-based power system: To meet our emissions reduction goals in the power sector we need more electricity to be generated from renewables and to power areas such as buildings, industry, and transport.
Third, the promotion of renewable and low-carbon fuels, including hydrogen, for hard-to-decarbonise sectors: Some sectors, like heavy transport and industry, are harder to electrify, so we need to invest in cleaner fuels to power them.
An integrated energy system will also rely on well-functioning markets, on better-planned infrastructure, and on progress of digitalisation in the energy sector.

Plenary keynote: Soteris A. Kalogirou

Soteris A. Kalogirou
Department of Mechanical Engineering and Materials Sciences and Engineering
Cyprus University of Technology
P.O.Box 50329, 3603 Limassol, Cyprus
Founding Member of the Cyprus Academy of Sciences, Letters, and Arts

Renewable Energy Systems: Current Status and Prospects in the World

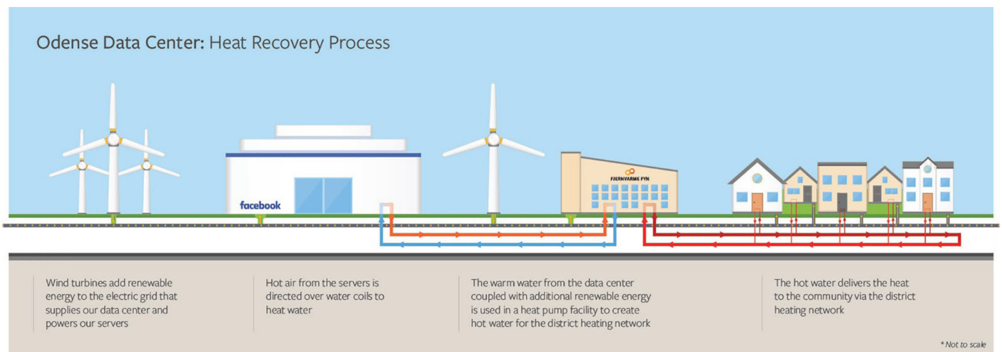
This presentation examines the current status of renewables in the world. The presentation starts with some facts about the climate change, global warming and the effects of human activities such as the burning of fossil fuels on the climate problem. It then examines the current status of conventional resources of energy such as oil, coal and natural gas and their reserves based on current consumption and known resources, followed by a general outline of the status of renewables in the world, which includes the shares with respect to conventional fuel use for electricity and power and jobs created. Then the basic forms of renewables are examined in some detail, which include solar thermal, both for low and high temperature applications, photovoltaics, hydro power, onshore and offshore wind energy systems and biomass/biofuels. In all these the basic technology is presented followed by the current status as well as the prospects of the technology and new research findings. Finally, some basic facts about the Renewable Energy Journal in which the speaker is the Editor in Chief are presented.

Plenary keynote: Lauren Edelman

Lauren Edelman
Energy Specialist, Facebook

Innovative Heat Recovery Solution - Facebooks commitment to renewable energy and energy efficiency

Facebook has set a goal to support our global operations with 100% renewable electricity in 2020 and beyond. Facebook has contracted over 5 GW of renewable energy, making us one of the largest corporate purchasers in the world. In 2019 we achieved 86% renewable electricity and are on track to meet our 2020 goal. Facebook is also committed to building some of the most advanced, energy-efficient data centers in the world. In Denmark, in addition to our typical efficient hardware, outside air cooling, and wind energy supply, we also installed infrastructure to capture the excess heat generated by our servers and recycle it into the local district heating system operated by Fjernvarme Fyn. Both our data center and Fjernvarme Fyn's heat pump facility were located and designed with heat recovery in mind from the outset of the project in 2014. The current goal is to recover and donate 100,000 MWh of energy annually from our servers — enough to warm 6,900 homes. The project is among the largest data center heat recovery solutions in the world. The presentation will discuss Facebook's commitment to renewable energy and energy efficiency, with a focus on the innovative heat recovery solution that evolved from a multidisciplinary team of Facebook and Fjernvarme Fyn engineers, architects, designers, facility operators, and energy professionals who worked to test the limits of commercially available technology at scale.



Lina works as a Lead Engineer for the UK consultancy FairHeat, which specialises in heat networks. She works to ensure and improve function and performance of heat networks, existing and under construction.
Lina is originally from Sweden and has a background in sustainable city development.

Potential of unutilised waste-heat possible to incorporate into UK district heating production

Lina Aglén (presenter) lina.aglen@fairheat.com

Provision of heat to buildings from district heating in the UK is targeted to increase from 2% in 2018 to 18% by 2050. The investment cost associated with this growth will be several billions of pounds, where a significant portion of the capital invested in district heating goes towards enabling the generation of heat. But what if there was no need to generate new heat to supply a district heating network?

The scope of this case study is to investigate a delimited portion of the potential of currently unutilised heat with the possibility to supply district heating networks in the UK. Waste heat is produced from a number of sources today. The study investigates the potential in the industrial sector, from wastewater treatment facilities and from the existing UK waste incineration plants.

A quantitative analysis is carried out to compare the identified potential with the current UK heat demand and investigate the potential impact on the UK carbon emissions. The calculations indicate a reduction of 14% in the required UK total domestic heat supply, despite only including a limited fraction of the available waste heat potential.

Keywords: Waste heat potential, district heating, reduce emissions, decarbonising heating, energy systems

Lisa Altieri studied sales engineering and product management with a focus on energy engineering at the Ruhr-University Bochum (RUB). Since 2016, she works on heat utilisation concepts as a research assistant at the Chair of Energy Systems and Energy Economics at the RUB.

Selecting the right heat source in an ultra-low temperature heating network

Lisa Altieri, Department of Energy Technology Ruhr-University Bochum; Michel Gross, Department of Energy Technology Ruhr-University Bochum; Tobias Reiners, Department of Energy Technology Ruhr-University Bochum.

Lisa Altieri (presenter) lisa.altieri@ruhr-uni-bochum.de

To meet the challenges of climate change, the German government is constantly increasing the efficiency standards for new residential buildings in Germany. The decreasing supply temperatures of heating systems enable the integration of previously unused renewable energies on a larger scale. The approach is to make one heat source available for several consumers in an ultra-low temperature heating network. The crucial question is this: "What is the best heat source to cover the heat demand of the residential buildings?" The use of renewable heat sources underlies various restrictions regarding the availability of resources, the availability over time and the achievable temperature levels. Considering these restrictions, the study elaborates four different heat source systems. These include groundwater wells, geothermal collectors, shallow geothermal probes and unglazed solar collectors in combination with an ice storage tank. The study examines the application of these source systems for a model area with 50 consumers. A methodology is developed to evaluate the influence of the heat source subsystem on the overall system. For this purpose, three relevant subsystems were identified. These are the heat pumps in the buildings, the distribution network and the type of heat source. The suitable heat source is selected according to the criteria of local and technical feasibility, space requirements, climate neutrality and costs.

Keywords: Renewable heat sources, ultra-low temperature network, shallow geothermal systems, solar thermal system, heat pumps

Helge Averfalk, PhD, assistant professor in energy technology at Halmstad University where he works with research questions related to low temperature district heating.

Low-temperature excess heat recovery in district heating systems: The potential of European Union metro stations

Helge Averfalk, School of Business, Engineering and Science, Halmstad University, PO BOX 823, SE 30118 Halmstad, Sweden; Urban Persson, School of Business, Engineering and Science, Halmstad University, PO BOX 823, SE 30118 Halmstad, Sweden

Helge Averfalk (presenter) helge.averfalk@hh.se

This paper presents an assessment of the excess heat recovery potential from EU metro stations. The assessment is a sub-study on low temperature recovery opportunities, explored in the H2020 ReUseHeat project, and consists of spatial mapping of 1994 underground stations with quantitative estimates of sensible and latent heat, monthly and annually, attainable in rejected platform ventilation exhaust air. Being a low-temperature source, the assessment conceptually anticipates recovery of attainable heat with compressor heat pumps to facilitate the temperature increase necessary for utilisation in district heating systems. Further, the paper explores the influence on useful excess heat volumes from low-temperature heat recoveries when distributed at different temperature levels. The findings, which distinguishes available (resource) and accessible (useful) excess heat potentials, indicate an annual total EU28 available potential of ~21 PJ, characterised by a certain degree of seasonal temporality, and corresponding accessible potentials of ~40 PJ per year at 3rd generation distribution, and of ~31 PJ at anticipated 4th generation conditions. Despite lower accessible volumes, utilisation in 4th generation systems are naturally more energy efficient, since relatively less electricity is used in the recovery process, but also more cost-effective, since heat pumps, at lower temperatures, can be operated at capacities closer to design conditions and with less annual deviations.

Keywords: Excess heat recovery, district heating, heat pumps, geographical information systems, metro stations

Federico Bava works as a consultant at Ramboll Head Quarter in Copenhagen in the Department of District Energy Planning & Infrastructure. His main areas are the planification and simulation of district heating and district cooling systems. Federico Bava holds a Ph.D. from the Technical University of Denmark on the topic "Modeling of solar collector fields for solar heating plants in district heating systems" in collaboration with the Danish company Arcon-Sunmark.

Feasibility analysis of renewable DHC concepts in different climatic zones

Fabian Bühler, Ramboll Denmark; Joao Elias, Ramboll Denmark; Frederik Palshøj Bigum, Ramboll Denmark; Joaquim Romaní Picas, IREC Spain; Aleksandar Ivancic, IREC Spain; Pernille Overbye, Ramboll Denmark

Federico Bava (presenter) fbava@ramboll.com

The heating and cooling (HC) of buildings with renewable energy (RE) has the potential to considerably reduce their environmental impact. Providing this HC through district energy systems has several benefits for the consumers, e.g. economy of scale and security of supply. The development and demonstration of new fully RE concepts for district heating and cooling (DHC) is important to increase the number of such systems in Europe and to determine the optimal solutions for any location. In this work the feasibility of 4 DHC concepts was investigated based on a developed method for due diligence. The analysis included a technical evaluation of the systems components and performance evaluations conducted in energyPRO. Additionally, the transferability of the concepts to other locations was investigated. The examined systems integrate RE technologies including: solar concentration, absorption cooling, biomass boiler, thermal storage and evaporative cooling. The implementation of the analysed concepts will be carried out within the H2020 project WEDISTRICT. The results show that the DHC concepts developed for demo sites in Spain, Romania, Poland and Sweden are feasible at their respective location and can cover the annual HC demand. Their transferability to other climatic zones is limited by the locally available energy sources. For scaling up the demonstration concepts it was found that the scalability of storages is crucial for variable RE sources integration.

Keywords: District heating, district cooling, feasibility analysis, due diligence, energyPRO, renewable energy, climate transferability

Roman Geyer is as a research engineer in the competence unit Integrated Energy Systems at the AIT Austrian Institute of Technology GmbH. His areas of responsibility include leading tasks and projects of international projects with focus on district heating and cooling.

Implementation of low-temperature district heating and its benefits

Roman Geyer, AIT Austrian Institute of Technology GmbH; Harald Schrammel, AEE - Institute for Sustainable Technologies; Karl Ponweiser, TU Wien – Institute for Energy Systems and Thermodynamics

Roman Geyer (presenter) roman.geyer@ait.ac.at

Third generation district heating (DH) with high supply temperatures was implemented when fossil fuels were still being used and buildings had very high heating requirements. In the future these conditions will change, and DH will rely on alternative sources forming the fourth generation of district heating (4GDH). While several 4GDH systems are already in operation in Scandinavia, there are only a few systems in the rest of Europe. To achieve the climate and energy targets, however, a significant reduction in the temperature level in all DH networks is necessary to decarbonize the energy system sustainably.

Different case studies of low temperature DH networks across Europe were analyzed and compared. Relevant key components and technologies were determined and the influence of reduced system temperatures on the entire DH system evaluated. The assessment was done by comprehensive calculations and detailed analyses of existing DH networks.

The main outcomes are the systematic and scientifically investigation of the potentials and effects of temperature reductions in DH networks. Thus, a well-founded cost-benefit analysis of measures for temperature reduction in heat networks is prepared, which serves as an essential basis for the development of new business models. Based on this, targeted implementation of the measures and thus a substantially accelerated reduction of temperature levels can be achieved.

Keywords: Low-temperature district heating, Benefits and effects, Implementation barriers and solution options, Transformation paths

Stefan Holler is professor at HAWK. His research fields cover DHC, CHP and RE systems with a focus on technologies for transformation of energy systems. He avails of significant experience in the management of diverse national and international projects. Stefan Holler is vice chairman of ETP DHC+.

Feasibility study on solar thermal process heat in the beverage industry

Stefan Holler, Abdulraheem Salaymeh, Adrian Winkelmann, HAWK University of Applied Sciences and Arts at Göttingen;

Stefan Holler (presenter) stefan.holler@hawk.de

Solar thermal (ST) energy provides only a minor percentage of the thermal demand of industrial processes globally. A feasibility study for the production facilities of a beverage company analyses the integration of Concentrating Solar Thermal (CST) technology into the existing steam system. For this purpose, CST collectors are integrated into the steam line to cover the base load of the demand when solar irradiation is available. A full-scale solar plant with 2.000 m² aperture area and a thermal power of 1 MW and its industrial-urban symbiosis are modelled and simulated under the specific boundary conditions of the industrial site. Beyond a ST solution for the production processes, the integration into a wider heat network that is connected to a district heating system (DHS) of the nearby municipality is elaborated. The results show that the heat production costs are in the range of 0,03 - 0,07 EUR/kWh. The CST plant at the industrial site has the potential to save about 150.000 L of fossil fuel oil per year and thus to prevent the emission of 450 tonnes of CO_2. Results of an economic analysis show a payback period between 6 to 10 years depending on the extent of subsidies.

Keywords: Solar process heat, Concentrating Solar Thermal technology, District Heating System, energy system modelling

Dr. Anna Kallert is head of the research group "urban heat systems" at the Fraunhofer IEE in Kassel (Germany). Her research focusses on evaluation, simulation and optimization of low-temperature district supply concepts based on renewable energy sources.

A Showcase Project: 4th Generation District Heating in Moosburgan der Isar (Germany)

Anna Kallert, Fraunhofer Institute for Energy Economics and Energy System Technology IEE; Robert Egelkamp, Fraunhofer Institute for Energy Economics and Energy System Technology IEE; Ulrich Bader, Bader Energie GmbH; Dietmar Münnich, DME-Consult GmbH; Lisa Staudacher, DME-Consult GmbH; Hannes Doderer, Institute for Climate Protection, Energy and Mobility

Anna Kallert (presenter) anna.kallert@iee.fraunhofer.de

With regard to the decarbonisation of the heating sector, District Heating is of paramount importance considering its potential for the efficient utilisation of renewable energies and waste heat sources. Against this background, the transformation and expansion of an existing heating network in the city of Moosburg an der Isar is planned within the "District Heating 4.0" funding programme of the German Federal Office of Economic Affairs and Export Control. The innovative concept involves a heat supply based entirely on renewable energies and industrial waste heat. In particular, the integration of unused waste heat from mechanical and chemical industrial processes enables an ecologically and economically optimal supply concept. Depending on the temperature level, the waste heat is fed into the grid directly or by an intermediate heat pump operated by photovoltaic or CHP. In addition, solar thermal systems on roofs and open spaces are integrated into the grid and optimised in terms of efficiency by using a seasonal storage. Biomass boilers operated by woodchips of waste wood cover peak loads as well as part of the base load and guarantee the security of supply. In addition to the technical design process, the analysis of legal as well as economic aspects is a key element of this first phase of the project. In further project phases, the implementation of the heating network, the monitoring of the energy flows and the ongoing acquisition of new customers will be carried out.

Keywords: 4GDH, waste heat, solar thermal feed-in, seasonal storage

Brage Rugstad Knudsen is a research scientist at SINTEF Energy Research. He holds a PhD in Engineering Cybernetics from NTNU - Norwegian University of Science and Technology. His research interests are control and optimization of integrated energy systems, district heating and hydrogen production.

Demand-side management for reducing peak-heating costs in a local low-temperature district heating grid with waste-heat utilization

Brage Rugstad Knudsen, SINTEF Energy Research; Daniel Rohde, SINTEF Energy Research; Harald Taxt Walnum, SINTEF Community; Marius Bagle, SINTEF Community

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Low-temperature district heating (LTDH) grids extend the options for using local low-grade waste-heat sources. Such sources may exhibit a high variability in available heat and temperature level. This is the case for a local LTDH under development in Trondheim, Norway, which will receive waste heat from an ice-skating rink with large daily and seasonal variations. The LTDH will be connected to the city's primary DH grid for covering the remaining heat demand. Demand-side management (DSM) can be used to shift or curtail flexible heat loads of buildings connected to the LTDH grid and hence for saving peak-heating costs by means of the heat withdrawal from the primary DH grid. We compare operations with and without DSM for the LTDH with aggregated demand profiles for the planned residential and commercial buildings in the area and consider yearly savings in heating costs through a seasonal representative-days approach. For the DSM, we present a Modelica-based optimal-control scheme which connects the least-cost heat-supply problem of the LTDH operator with the buildings' optimal response through a price signal generated by the operator. We quantify results on the case study and present sensitivity analysis on demand and peak-heating cost volatility.

Keywords: low-temperature district heating, demand-side management, waste heat utilization, optimal control, price signals

Hironao Matsubara's research fields are statistics database, scenario study, policy framework and business model of renewable energy in Japan. He is an editor in chief of Renewables Japan Status Report since 2010.He took a degree as doctor of Engineering from Tokyo Institute of Technology in 1990.

Heat Roadmap Japan: Smart energy system combining renewable energy and district energy to decarbonize urban area in Japan

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To address climate change and formulate effective energy policies in accordance with the Paris Agreement, Heat Roadmap Europe is an informative reference for decarbonization of heat sector and evolution of the 4th generation district heating. We study different scenarios focusing on the urban areas of Japan to achieve 100% renewable energy by 2050 with smart energy systems and sector coupling. EnergyPLAN models are adopted to assess the feasibility of energy transition through decarbonization in the domestic electricity market, and heat and transportation sector. The model incorporates the present situation and potential of district heating system in urban areas in Japan, and the possibility of decarbonization of heat sector by renewable energy and energy efficiency. Both locally and regionally available renewable energy resources should be utilized for district energy system in the urban area of Japan. The model is optimized for energy efficiency through comprehensive use of unused heat resources such as exhaust heat, geothermal, and sector coupling with electricity market according to regional characteristics. Finally, we construct a heat roadmap of the urban area including Tokyo Metropolitan with a smart energy system for district energy.

Keywords: Renewable Energy, Smart Energy System, District Heating

Wiebke Meesenburg is postdoctoral researcher at the Section of Thermal Energy, Technical University of Denmark. Her research focusses on heat pumps and refrigeration systems, especially their integration into district heating systems, digital twins and increasing the ability of flexible operation.

Flexible heat supply from supermarket refrigeration systems

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Excess heat from supermarket refrigeration systems may be used to provide heating to the building or a local district heating grid. Thereby, the system acts as a combined heating and cooling unit coupling the heating, cooling and power sector. The heating and cooling supply may be decoupled by using an additional heat source. Thereby, the heat supply may adapt more flexibly to the heat demand or act as flexible load to supply ancillary services to the power grid. Within this work, the integration of an additional heat source into a supermarket refrigeration system is studied. It is assessed, how the system should be operated optimally to achieve the highest thermodynamic and economic performance, while ensuring optimal utilization of the existing compressor capacity. The analysis covers the supply of district heating at different temperature levels. Further, the availability for ancillary service supply is assessed. The analysis is conducted using a dynamic model of a CO2-refigeration system of a supermarket located in Nordhavn, Copenhagen. The results are evaluated based on overall system performance, i.e. coefficient of performance and exergy efficiency, and operational cost. Based on these, recommendations regarding the optimal operation strategy are derived. The most promising operation schemes for the different district heating scenarios are presented, including low temperature and ultra-low temperature district heating systems.

Keywords: Combined heating and cooling, Excess heat, Supermarket, District heating, Ancillary services

Francesco Mezzera has a Master of Science degree in Energy Engineering from Politecnico di Milano. After writing his master thesis about the role of hydrogen and electro-fuels in the Italian energy system, he is now working as a research fellow at the Energy Department of Politecnico di Milano.

District heating potential in a hydrogen-based energy system - An exploratory focus on Italy

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The target of the full decarbonisation by 2050 requires high penetration of renewables (RE), with the inevitable development of overgeneration situations in the energy system. Hydrogen and electro-fuels could play a key role in hard-to-abate sectors and in grid balancing. By means of the developed NEMeSI model we study the Italian future energy mix, including several Power-to-X (P2X) options to accommodate high REs introduction. The model is set to solve a linear optimization problem, by optimizing the use of resources through the minimization of the supply costs. The use of excess power from renewables is evaluated in solutions such as hydrogen production and electro-fuels synthesis, coupled to power to heat and storage systems. The model studies the Italian case in a decarbonised scenario and provides an estimation of potential waste heat recovery from the implemented P2X processes, differentiating from low to high temperature waste heat. Waste heat can be used for district heating purposes or for power generation via organic Rankine cycle. Power-to-gas plays a relevant role in fossil sources substitution while seasonal storage enables a convenient use of excess renewable power. Both high and low temperature heat recovery show a potential in the order of tens of TWh. The potential use for district heating is relevant although, depending on the boundary conditions of the scenario, there might be a preference for the use of high temperature heat for power generation.

Keywords: Power-to-X, potential waste heat recovery, electro-fuels, hydrogen, district heating

Peter North is a part-time PhD student in the Centre for Process Systems Engineering at Imperial College London, and Director and Practice Principal of his consultancy, Calorem Ltd. His interests are in urban decarbonisation and the move towards a circular economy approach to building heating.

A pathway towards the heat autonomous city

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Building space heating is a low-quality application needing only to maintain room temperatures at 21°C. In cities without a tradition of district heating, the heating demand is met by the use of natural gas that is responsible for more CO2 emissions than either its transport or electricity supply. The combustion of gas also contributes towards poor air quality and its import leaves consumers vulnerable to volatile international energy markets and the risk of supply curtailment by external agents. European cities have sufficient low-quality energy resources in the form of waste heat and local renewable energy sources to eliminate the need for gas in heating. The use of heat networks operating in conjunction with heat pumps offers the opportunity to utilise the local energy resources and transition towards heat self-sufficiency. This research investigates the use of advanced process control and real-time optimisation techniques to model district-level heat networks operating at near-ambient temperatures. The aim is to maintain warm and cold sinks to allow the more effective use of energy in building heating and cooling. This is achieved through the reuse of heat rejected from cooling processes, and increasing heat pump and compression chiller co-efficient of performance (CoP). The control objectives are to maximise heat pump and chiller CoP and minimise primary energy consumption while accounting for multi-variable process constraints.

Keywords: Energy savings, smart energy management, advanced process control, multi-objective optimisation, real-time optimisation, district-level energy networks, renewable energy, waste heat.

Henrik Pieper is a Postdoctoral researcher at Tallinn University of Technology at the Department of Energy Technology. His area of expertise is within the field of modelling thermal energy systems with the focus on heat pumps, refrigeration, district heating and cooling, heat sources and sinks.

Ranking of heat sources and sinks based on seasonal performance estimation and demands for heating and cooling areas

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Igor Krupenski, Tallinn University of Technology;
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Recent studies have analyzed suitable heat sources and sinks (HSS) for heating and cooling purposes. They showed the importance of HSS and the different characteristics they have in terms of temperature variations, accessibility, capacity limitations, long-term stability or distance to district heating and cooling networks. We present a study in which various HSS were investigated by analyzing the performance of electrical-driven heat pumps and chillers using them to provide heating and cooling. The coefficient of performance of heat pumps and chillers was calculated over the year based on thermodynamic models with the aim of supplying different kinds of heating and cooling customers. The performance was weighted according to the demands. Thereby, seasonal temperature and demand variations were considered. This method was applied to different demand profiles, such as existing and new residential buildings as well as to office buildings. Furthermore, the network supply and return temperatures were varied in order to investigate the potential increase of exploiting HSS. Groundwater, ambient air, seawater, lake water, river water, the district cooling network and sewage water were considered as HSS. The study was applied to Estonia, representing a north European climate. The outcome of the study is a ranking of several HSS that may be used for the supply of heating and cooling purposes. This ranking may improve the selection process of suitable HSS in the future.

Keywords: Cooling, COP, Energy Planning, Heating, Heat pump, Heat sink, heat source,

Tobias Reiners, born in 1987, studied mechanical engineering with a focus on energy and process engineering at the Ruhr University Bochum (RUB). Since 2016 he is a research assistant at the Chair of Energy Systems and Energy Economics at the RUB.

Waste heat from mine water in an ultra low temperature district heating network

Tobias Reiners, Department of Energy Technology Ruhr-University Bochum; Lisa Altieri, Department of Energy Technology Ruhr-University Bochum; Michel Gross, Department of Energy Technology Ruhr-University Bochum

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After the end of coal mining in Germany, the residential area "Water City Aden" is being built on the former industrial site of the Haus Aden coal mine. One of the six permanent pumping stations for mine water in the Ruhr area is located on the premises of the Water City Aden. To protect drinking water reservoirs and to ensure that no rising mine water reaches the groundwater level even after active mining has ceased, the mine water is pumped by the mining company at a temperature of between 26 °C and 30 °C. This case study investigates the heat supply of the district with 146 residential buildings. A 5th generation ultra low heating network is used at a temperature of 20 °C. The heat fed into the network comes from geothermally heated mine water. Decentral heat pumps in the buildings use the energy transported via the heating network as a heat source. The heat pumps achieve the temperature level for the heating system and domestic hot water preparation in the residential buildings. The results show that the heat pumps used work much more efficiently than with alternative heat sources due to their integration into the heating network. The CO_2 emission factor of the system is 0.08 tCO_2/MWh and the primary energy factor is 0,27. At the same time, the heat production costs of the system are comparable to those of a 4th generation heating network with a natural gas fueled combined heat and power unit.

Keywords: 5th generation, ultra low temperature district heating network, waste heat, minewater, decentral heat pumps, german case study, residential area

Dr Akos Revesz is a Senior Research Fellow at London South Bank University. He is an experienced researcher in the field of sustainable energy systems. He specialises in low carbon renewable and secondary energy utilisation for heating and cooling applications.

Waste heat integration into heat networks; a UK wide assessment

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The provision of heating and cooling produces more than one-third of the UK's CO_2 emissions and represents about 50% of overall energy demand. Reports by the UK Government (BEIS) indicate that heat networks could supply up to 20% of building heat demand by 2050. Currently the focus is the development of 4th and 5th generation energy networks which seek to use lower temperatures to make more renewable and secondary sources available and reduce distribution losses. This presentation will introduce a research project investigating the viability of integrating waste heat sources into heat networks. It will detail the results of estimated numbers, size and location of different waste heat sources across the UK. Analysis of individual sources, including waste heat from low and high-temperature industrial processes, sewers, data centres, electrical distribution networks and underground railway tunnels will also be detailed. Alongside the likely heat output from each source type, carbon and energy-saving potentials where applicable will also be shown. Standard heat recovery system arrangements for each waste heat source, alongside cost estimates and a heat benchmark for each source category, will also be presented. A macro-level perspective, applying benchmarks and learning thus far to estimate the scale of opportunity for each source type across England, Wales and Northern Ireland will be concluded.

Keywords: Waste heat, Heat Networks, UK

Dirk Vanhoudt is senior researcher in the Energy Technology Unit of VITO and EnergyVille. His main research topic is the development of next generation district heating grids. Dirk has coordinated the STORM and the TEMPO proposals and is project coordinator of TEMPO.

TEMPO - Results of the first temperature reduction measures in the demo sites

Dirk Vanhoudt, VITO/EnergyVille; Aurelien Bres, AIT; Paolo Leoni, AIT

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In the Horizon 2020 project TEMPO, solutions to reduce the temperature levels in district heating (DH) networks are developed and demonstrated. In TEMPO, six technological innovations are developed to TRL 7-8 and demonstrated. The technologies mainly focus on digitalisation of networks, ranging from smart control, fault detection and correction in substations and building installations to visualisation tools. Furthermore, some network components are investigated and further developed, namely a 3-pipe network concept and decentralised buffer systems. Besides these technologies, innovative business models are studied to encourage lower temperature levels in DH networks.

The two demonstration sites are of a very diverse nature. One is a small, new built LT DH networks in a rural town in the Nuremberg (Germany) area for which the reduced temperatures could increase the energetic efficiency and profitability of the network. The second is a network branch of the large, existing HT network in Brescia (Italy) which could at a later stage be coupled to a sustainable source, if the temperature levels could be reduced.

We present the analyses of the results of the first testing campaign, in which the temperatures in the networks were reduced. The effect on primary energy demand, greenhouse gas emissions, heat distribution losses, average return temperature, share of residual and renewable energy sources and some demo specific indicators were studied for this period.

Keywords: digitalisation, temperature reduction, demonstration

Jelena Ziemele is an International level Energy professional, Expert and Project Manager. She has than 25 years of experience grounded by theoretical (PhD in Environmental Engineering) and practical experience in Private, Public and Academic sectors.

A multi-factorial decision support tool for integration of small-scale industrial heat pumps and solar PVs into a district heating system

Jelena Ziemele, JSC "Rigas Siltums"; Normunds Talcis, JSC "Rigas Siltums"; Ugis Osis, JSC "Rigas Siltums"; Elina Dace, University of Latvia, Riga Stradins University

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During the last decade, energy efficiency in district heating systems (DHS) has significantly increased for many reasons, among them – improved use efficiency of alternative energy sources. The paper presents a decision support tool of an integrated system that provides implementation of industrial heat pumps (HPs) and solar PVs into an existing DHS. The study develops four different scenarios of HPs' installation: a central HP, HP installation for improved flue gas condenser efficiency of the DHS's boiler house, use of the DHS's return heat carrier as a heat source for the HP (implementation of high-temperature HP), and use of consumers' sewage water as a heat source for the HP. The multi-factorial decision support tool allows for energy, economic, and environmental assessment of HPs and solar PVs in increasing the DHS's efficiency. The paper studies the effects of different fuel price scenarios and identifies the electricity/gas price ratio to achieve an economically feasible performance of the integrated system. In the system, the power-to-heat concept is realised, and solar PVs serve as a power price-balancing instrument. A sensitivity analysis is carried out by using the one-at-a-time method. The research is based on a case study of an autonomous district heating system in a medium-sized urban settlement with an average heat production of 8.3 GWh/a. The primary heat consumers are apartments and industrial buildings.

Keywords: District heating, multi-factorial analysis, heat pump, solar power

Weena Bergstaesser is a Research Associate at the Department of Solar and Systems Engineering at the University of Kassel. She focusses on the transformation of the district heating networks including the use of renewable energy systems.

Lessons learned from Excess flow analyses for various district heating systems

Weena Bergstraesser; Andreas Hinz; Janybek Orozaliev; Klaus Vajen

all from: University of Kassel, Institute of Thermal Engineering, Department Solar and Systems Engineering, Kassel, Germany

Weena Bergstraesser (presenter)

Many substations in existing district heating (DH) grids do not achieve an optimal efficiency which often corresponds to high return temperatures. In order to achieve lower return temperatures, the Excess flow method was developed in the IEA DHC Annex VII “Improvement of Operational Temperature Differences in District Heating Systems”. It allows to identify those customers that contribute the most to a high return temperature. The Excess flow analysis has been conducted for three existing DH grids in Germany. Two of these are large urban DH grids. In the first case around 60% of all substations have been analyzed, in the second case the analysis focused on 207 substations in a subgrid, the third case is a small grid in a rural area. In addition to a comparison of the three conducted analyses it will be discussed how the target temperature difference influences the ranking of substations and how this correlates with the grid’s temperature levels. Generally, the Excess flow method has proven to be highly accurate in identifying faulty substations which has been shown by inspecting high priority substations from the ranking. Frequent failures, identified during inspections, will be listed. When it comes to implementing measures to eliminate faults and reduce the return temperature in an existing DH network, one main obstacle is the profitability of such measures. That is why an outlook on possible advantages of return temperature reduction such as grid capacity will be given.

Keywords: Excess flow method, return temperature reduction, transformation to low temperature systems, substations

Andra has devoted her career to study energy efficiency in buildings from different angles, incl. development of technologies, diffusion of technologies, intervention policies to foster diffusion. She is also an expert in application of System Dynamics modelling to study complex systems.

Achieving Positive Energy Block in historic urban environment: simulation and evaluation of alternative scenarios

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The goal of this study is to assess different scenarios to reach Positive Energy Block in densely populated urban environment taking into account both reduction of impact on climate change by assessing complementary energy consumption curves of different types of buildings, optimisation of local renewable energy production, consumption and storage, and architectural and urban values by creating a functional and social mix, contributing to urban regeneration. A system dynamics model was created based on hourly energy balance. Different energy saving and energy producing technologies of flexible energy system, are included in the model. Different energy efficiency renovation scenarios of buildings is studied. Energy can be supplied either by locally producing in the block with RES, heat pumps or externally by district heating and electricity network. Waste energy from different sources is used as energy source. Accumulation technologies, shifting energy consumption for commercial consumers as well as electrical vehicles are simulated. Different return temperature of district heating are studied to understand behavior of the system over the time. The model is used to compare scenarios: (1) energy efficiency and RES first; (2) architectural values first; (3) compromise between energy efficiency, RES and architectural values. In addition to that, optimization scenario is carried out to find the most economically and environmentally feasible solution.

Keywords: energy communities, urban regeneration, positive energy block, energy efficiency, renewable energy sources

Stef Boesten is a PhD candidate in the multidisciplinary research program Safety in Urban Environments at the Open University. His work focuses on identifying technically and socially optimized approaches for retrofitting urban areas with ultra-low temperature district heating and cooling systems.

Water to water heat pump for district heating: modeling for MILP optimization and application to a real case study

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Water sourced heat pumps have the potential to play a large role in decarbonizing urban heat supply, for example in ultra-low temperature district heating systems when high temperature heat sources are not available. Understanding the effects of size and operation of heat pumps on the general performance of an energy system is not straightforward. Existing methods based on thermodynamic models are only applicable in a small range of circumstances, while models that assume constant COP fail to capture temperature dynamics.

With this work, we present a generic linear model for water source heat pumps. We developed this model by fitting 251 data points from manufacturer data sheets of water-to-water and brine-to-water heat pumps in the 100 kWth to 1600 kWth range. The model is able to consider dynamic efficiency and temperature dependent linearization and is applicable for use in mixed-integer linear programming (MILP). For this, we use the energy hub modelling tool originally built by Gabrielli et al. (2017).

Using the model, we have optimized the design and operation of a heating system for a residential neighborhood with 850 apartments and a shopping center in the Netherlands. We compared the optimal size and operation schedule of heat pumps as a stand-alone solution with several district heating configurations and grid temperature levels.

Keywords: Heat pump, MILP, 5GDHC, energy hub, optimization, district heating and cooling

Hermann Edtmayer is a research assistant at Graz University of Technology, Institute of Thermal Engineering and has his main field of work in the topics of innovative thermal energy supply systems and spatial energy planning.

Sector Coupling Potentials of a 5th Generation District Heating and Cooling Network

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In this paper the topic of sector coupling is discussed with a specific focus on utilising extra profits for the operation of an existing 5th generation district heating and cooling network (5GDHC) in Zürich, Switzerland. It was investigated, how the heat energy production through large industrial heat pumps and the total heat capacities of the 5GDHC system can provide flexibilities for power to heat applications. The intention was to take advantage of the European electricity day ahead market or provide grid stabilisation services to the electricity balancing market of the respective country to obtain a lower heat energy retail price for the customers of the 5GDHC network. Therefor in a first step the special requirements of a 5GDHC system were implemented into a previously developed co-simulation tool for large district heating systems (see Figure 1: adapted transfer station in IDA ICE). Followed by the georeferenced modelling of the investigated network using IDA ICE, QGIS and PostgreSQL databases. In a second step the system flexibilities were systematically investigated with respect to key performance indicators like heat capacity, response behaviour or electrical energy consumption as a function of the thermal comfort in the connected buildings. The third step comprised of the implementation of a model predictive control into the simulation tool to apply forecasts of energy price, outdoor temperature or heat demand to the operation strategy of the system.

Keywords: 5GDHC, sector coupling, power to heat, model predictive control, day ahead and grid balancing market

Thomas Estermann has been working as a research assistant at the FfE e.V. since 2015 after completing his Master's degree in Applied Research in Engineering Sciences. He is currently doing his PhD at the Technical University of Munich.

Method for determining the feasibility of Grid andAncillary Services by Smart Meters

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The energy transition leads to change on the generation and consumption side and calls for progress in the digitalisation, which includes the rollout of intelligent metering systems (iMSys). This rollout offers potential for decentralized assets to take response regarding grid and ancillary services through their equipment with iMSys. The introduction of iMSys is performed throughout Europe and the required functionalities vary by each country. Furthermore, the iMSys is part of an ongoing development process, which offers the opportunity of introducing additional functions to meet service specifications. The paper describes a method for analysing requirements of services and technical functions of iMSys. The House-of-Quality (HoQ) method is adapted such that the importance of individual iMSys functionalities can be analysed and the meaning of single requirements can be evaluated. As a result, the method allows determining which services can be provided by assets through their equipment with iMSys and which functions are still needed to close existing gaps. Applying this method to the situation in Germany shows that the first iMSys-Generation fulfils 43 % of the requirements, enabling five services. The target generation fulfils 86 % of the requirements and thus offers 17 services. Only three iMSys functions are additionally necessary for enabling all considered services. The HoQ can be applied to any country by adapting the iMSys functions to those available in that country.

Keywords: Distribution Network, Smart Metering, Flexibility, Grid and Ancillary Services, Smart Grid

Luca Ferrari, Mechanical Engineer with a Business Master Degree, has spent the last 5 years in the US working on projects to increase industrial plant's energy efficiency. He is now working for Optit srl, where he is leveraging digital tools to improve the performance of complex energy assets.

Integrated planning of multi-energy systems (PlaMES): comprehensive modelling framework and decision support tool

Luca Ferrari, Optit Srl; Angelo Gordini, Optit Srl; Marco Franken, Rheinisch-Westfalische Technische Hochschule Aachen; Henrik Schwaeppe, Rheinisch-Westfalische Technische Hochschule Aachen; Paolo Paronuzzi, Università di Bologna; Anotnio Punzo, Università di Bologna;

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The European Union's commitment towards a carbon-neutral economy could be accomplished by a synergistic implementation of measures including efficiency increase, Renewable Energy Sources expansion and multi-energy infrastructures coupling. These objectives achievement depends on a continuous technological innovation: from the energy conversion unit's improvement to energy storage; from electric thermal/cooling generation to chemical commodities synergies; from markets integration to digitalization. The proposed integrated planning, object of the H2020 project PlaMES, is designed to determine the optimal target system, including the investment trade-off amongst different technologies, infrastructure configurations and emissions reduction. The objective function minimizes the overall energy system costs including capital (CAPEX) and operational (OPEX) expenditures with a long term vision to 2050. Integration of central and decentral perspectives is used to solve the problem, where national data aggregation about current and future energy macro-systems interact with a local model with an increased level of detail and granularity to manage a specific focus area. The envisioned decision support tool will model the investment choice for energy supply assets, transmission and distribution infrastructures, investigating electricity, gas, heating/cooling and mobility synergies to meet future energy demand patterns, aiming at an efficient transition to a sustainable energy system.

Keywords: Multi-Energy, Energy Sector Coupling, Investment trade-off, central planning, decentralize planning, energy infrastructures, decision support system, thermal/cooling generation

Hans-Christian Gils is group leader on Energy Systems Modelling at the Energy Systems Analysis department of the German Aerospace Center (DLR). He holds a degree in physics and received his PhD for a thesis on energy sector coupling.

The Contribution of Flexible Sector Coupling to Fully Renewable Electricity Generation in Australia

Hans-Christian Gils, Yvonne Scholz, Hedda Gardian, German Aerospace Center (DLR), Department of Energy Systems Analysis

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With the sharp decline in costs, wind and especially solar power generation has been strongly increasing in Australia over the past years. Given its abundant space and high-quality potential, Australia has great opportunities to cover its complete energy demand from renewable sources. This case study evaluates the role of flexible sector coupling in a climate-neutral energy system for Australia, using the established high resolution energy system model REMix. More specifically, it addresses the question how it can contribute to the balancing of renewable power supply, complementing storage and transport of energy. Energy sector coupling refers to direct or indirect electrification of the transport and heating sector through electric heating, electric driving and the usage of synthetic fuels. All these options are included in the model. The model results show that with the expected cost developments, utility-scale photovoltaics (PV) would be the cheapest energy source in Australia. This would be supplemented by onshore wind power generation and roof-mounted PV. A significant contribution to balancing is made by the power grid and pumped hydro as well as battery storage. Of greater importance, however, is the flexibility provided by sector coupling. This applies in particular to the flexible production of hydrogen, which is stored in large storage facilities and transported via long-distance pipelines, but also to load management of electric vehicles, cooling and heating.

Keywords: energy systems modelling, sector coupling, renewable energy, energy scenario, REMix, Australia

Elisa Guelpa is an Assistant Professor at Department of Energy at Politecnico di Torino. Her fields of interests are district heating network, multi-energy-system, optimization of energy systems, thermal storage, renewable energy.

Maximize the effects of district heating demand response in multi-energy optimization

Martina Capone, Politecnico di Torino; Elisa Guelpa, Politecnico di Torino; Giulia Mancò, Politecnico di Torino; Vittorio Verda, Politecnico di Torino

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Adoption of various production technologies to supply multi energy systems makes the selection of the operating strategies quite challenging, especially when storage units are available. Among the various options, it is possible to find an optimal solution, depending on the goal (minimum cost, emission, primary energy). The best solution depends on the loads (electric, heat and cold), the available technologies, the efficiencies, additional cost etc. The authors have developed a methodology for estimating the best operation of production technologies and storages on a daily basis, considering their efficiencies and their impact with the electric and thermal networks. The main novelty of the work is that demand side management (i.e. the possibility of acting on the user thermal behavior to changing the total thermal load) is included in the optimization. In such way the benefits achievable by demand response are maximized since tailored with the specific chacatreristics of technologies available (e.g. combined heat and power plants, heat pumps, absorption chillers, heat only boiler etc). Up to now, demand side management in district heating was applied to a predefined set of operational condition of the production side (i.e. demand response act once the production evolution in known, with the aim of minimizing costs); in this new perspective demand response is included in the plant operational management.

Keywords: demand side management, multi energy systems, thermal network, optimization, demand response,

Marnoch Hamilton-Jones studied Mechanical and Energy Engineering at Heriot-Watt University, Edinburgh and works at the AEE Institute for Sustainable Technologies in Austria. His work is focused on development and application of methods for analysing data from solar thermal and district heating systems.

Fault detection and optimization potential on the demand side of district heating systems

Marnoch Hamilton-Jones, Harald Schrammel, Jakob Binder, Ingo Leusbrock (all AEE INTEC)

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One of the main goals of 4th generation district heating (DH) is to facilitate the integration of renewable low-temperature energy sources and to reduce heat losses. Decreasing the required supply and return temperatures of heating networks plays a crucial role in achieving this goal. The Austrian project „T2LowEx" focuses on interventions on the demand side and on substation level to lower the return temperatures and thus the overall system temperatures. Together with four DH providers the most common faults and optimization potentials (e.g. change/cleaning of heat exchangers, adjusted control strategy, refurbishment of building side heating and hot water systems) were identified. A fault detection tool based on clustering algorithms was developed: it identifies customers that need improvement and gives additional information on the fault itself. Multiple methods were examined including k-means, Gaussian mixture models and various density-based clustering approaches. Optimization and maintenance measures were applied to several faulty customers and substations Their effect was evaluated with data monitoring, which showed an increase in temperature differences by 10 to 40 K. The evaluation of the clustering methods and the application of the fault detection tool will be presented as well as the monitoring results of the improvement of selected customers.

Keywords: 4th generation district heating, return temperature reduction, fault detection, clustering algorithms

Aleksandar Ivancic has a B.S. in mechanical engineering, and a Ph.D. in Thermal Science. He works as Senior Researcher at IREC with his interest is positioned within infrastructure planning, with a particular focus on energy systems and environmental impacts.

Evaluation of district energy systems with shared systems for heating and cooling generation

Aleksandar Ivancic and Joaquim Romaní, IREC; Maria-Victoria Cambronero, ACCIONA; Fabian Bühler, RAMBOLL; Jaume Salom, IREC

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Due to new thermal comfort demands, caused by higher internal heat gains, better insulation, but also by increasing temperature due to climate change, the cooling demand of buildings is rising. It is expected that many existing DH systems are going to include DC service, while new district energy systems are going to offer both heating and cooling from the beginning. Renewable district energy systems have multiple components for generating heating and cooling. Some of them might be used for both purposes, either simultaneously or alternatively. Concepts such as engineering costs or taxes might not be directly associated to cooling or heating generation. This makes more complex the evaluation of cooling and heating services energy, environmental, and economic results. A fair comparison of DHC with individual systems requires allocating inputs separately between the services. The paper presents a methodology for calculating different DHC system KPIs, distinguishing between heating and cooling ones. First it establishes the analysis boundaries for the RES DHC system. According to this, the methodology proposes a demand based and an investment based share factors that facilitate the heating and cooling KPIs calculation. As an application example, the methodology is applied to the evaluation of a real DHC case. The methodology is developed within the H2020 project WEDISTRICT and it will be further applied to compare different DHC configuration foreseen within the project.

Keywords: District heating, district cooling, renewable energy, key performance indicator, benchmarking

Joseph Maria Jebamalai is working as an innovation engineer at Comsof, Belgium and he is also a PhD fellow at Ghent University, Belgium. He graduated in Sustainable Energy Engineering from KTH, Sweden. His area of interest includes district heating and cooling networks and thermal energy storage.

An Automated Method to Design Multi-Source District Heating Networks with Integrated Thermal Energy Storage – A Case Study

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District heating systems are evolving towards well-integrated and distributed waste and renewable energy sources. Multiple sources are becoming an integral part of district heating systems. However, multiple sources are posing challenges in efficient routing of district heating networks. Therefore, optimization is necessary to choose the cost-efficient route and source allocation to the building demand points. Moreover, the future district heating networks have to be flexible enough to absorb the heat load variations and heat supply variations caused by intermittent renewable energy sources. One of the proven and cost-effective ways to provide such flexibility is integration of thermal energy storage. This paper aims at presenting the method for automated routing and designing of the multi-source district heating networks with the integration of thermal energy storage.

The developed method is implemented as a proof of concept in Comsof Heat, a GIS-based district heating network planning and dimensioning tool. This can help in calculating different scenarios fast and the tool can provide a network deployment cost estimation and return on investment calculations as well. A municipality (Wevelgem) from Belgium is used as a case study to demonstrate the developed method using Comsof Heat. Several scenarios with different possible source options and building demand points will be studied and their impact on network costs is compared. The best possible energy sources out of several given possibilities are selected based on the following parameters: source investment cost, energy production cost, carbon cost, or the combinations of the above. Then, the network routing is done to connect the building demand points and the selected energy sources. The impact of centralized thermal energy storage on network costs will also be studied for different scenarios. Finally, all the simulated cases with different source and storage options are compared to study the effect of design choices on costs and CO2 emissions.

Keywords:
Multi-source district heating systems, renewable energy sources, automated routing, district heating planning and dimensioning tool, scenario calculation.

Hicham Johra is a Postdoc researcher at Aalborg University. He works in the fields of building energy flexibility, building material characterization, and indoor environment quality.

Using data from smart energy meters to gain knowledge about building clusters connected to district heating networks: A Danish example

Hicham Johra, Aalborg University - Department of the Built Environment; Daniel Leiria, Aalborg University - Department of the Built Environment; Per Heiselberg, Aalborg University - Department of the Built Environment; Anna Marszal-Pomianowska, Aalborg University - Department of the Built Environment; Torben Tvedebrink, Aalborg University - Department of Mathematical Sciences

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District heating (DH) is a key element in the future 100% renewables energy grids of countries with a dominant heating season. DH is a sustainable heat supply that can use the energy flexibility of the connected buildings to perform demand-side management and balance intermittent renewables. However, to enable those strategies, plan network expansions and renovations, improve production and distribution efficiency (lower the supply temperature), and tackle distribution bottlenecks, a deeper understanding of the building stocks supplied by DH is required. Within the current context of the big data mining, the building sector is generating large data sets that can be analysed to comprehend the various energy usage profiles and characteristics of the different households and stakeholders. The recent systematic installation of smart energy meters in buildings enables the first large data analyses of city-scale clusters of buildings connected to DH networks. The current study tests different statistical and clustering analysis methods to identify the building characteristics and energy profiles of a small Danish town (1665 buildings) connected to a large DH system. An interactive web-based interface has been developed to present and share the analysis results with the professionals of the building sector and the DH utility companies. This work has been conducted with "R", a free programming environment that is specifically well-suited for statistical analysis of large data sets.

Keywords: time series analysis, smart energy meters, district heating, building cluster

Goran Krajačić is associated professor and head of Power Engineering and Energy Management Chair at the Faculty of Mechanical Engineering and Naval Architecture (FSB), University of Zagreb. Besides teaching at all levels, he coordinates FSB and SDEWES participation at several EU and national projects.

Modelling the water-energy nexus of the future smart island

Dino Kovačević, University of Zagreb - FSB; Goran Stunjek, University of Zagreb - FSB; Marko Mimica, University of Zagreb - FSB; Goran Krajačić, University of Zagreb - FSB

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Following the signing of the Paris Climate Agreement and the adoption of the European Green Deal, which aims to make Europe the first climate-neutral continent, research into the sustainable development of energy, water and environmental systems is increasingly focusing on studying the complex relationship between water and energy systems. Water system is being modelled using the EPANET model. EPANET is an open source software used for hydraulic modelling of water supply systems and analysis that includes optimizing the operation of pumps and water tanks, reducing electricity consumption etc. Optimal connection between water and energy system is studied using the Calliope tool. Calliope is free and open-source multi-scale energy systems modelling framework used for optimization analysis of the water-energy nexus. The approach was used for the analysis of a future water system on the Unije Island as part of the INSULAE project. Project also includes implementation of PV and battery system, which are modelled as part of an existing energy system. Different scenarios of water system management were studied. Using aforementioned approach optimal water tank volume was calculated, while preventing occurrence of unmet water demand. Moreover, scenario of using individual household water reservoirs was studied, while also preventing the occurrence of unmet water demand in each hour of a one-year time period.

Keywords: Smart islands, water, INSULAE, EPANET, integration of renewables, PV, battery, demand response, Demand Side Management

Shravan Kumar’s work deals with the modeling of the district cooling system in Gothenburg

Comparison of modelling approaches for operational optimization of district cooling networks

Shravan Kumar, Chalmers University of Technology; Maria Jangsten, Chalmers University of Technology;Torbjörn Lindholm ,Chalmers University of Technology;Jan-Olof Dalenbäck, Chalmers University of Technology;

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Techno-economic optimization models are key for analyzing the operation of district cooling system (DCS) and examining the impact of future investments. DCS has lower temperature differences and hence larger flows than in a district heating system. Thus, the accuracy to which the network is modeled has a significant impact on the reliability of the results. However, optimization programs coupled with physically based network models are computationally expensive to run for long time periods. Therefore, the aim of this study is to develop simplified methods to represent the network in numerical models, analyze the performance of these methods and compare the accuracy of representation of the network. The first method includes the operation costs associated with the network as ‘additional costs’ for each district cooling plant. In the second method the network is simplified into a radial network by creating a number of demand clusters, which are then used to develop ‘linked cost functions’, coupling each cluster with every plant. Thus, the topology of the network is represented numerically. The comparison is based on the DCS in Gothenburg, Sweden. The results indicate that both methods yield similar results for the pumping costs, but in the second method, the network-based constraints have a larger effect on the DCS operation and thus provides a better representation of the network.

Keywords: Optimization modeling, district cooling systems, district cooling networks, Energy system modeling

Ari (M.Sc. Tech.) is specialized in data and investment analysis in the field of real estate and energy efficiency. He has been teaching for real estate valuation at Aalto University and works also as editor-in-chief of Land Use Magazine Finland.

Modelling one hour level heating energy consumption of buildings – can AI algorithms enhance the understanding?

Ari Laitala

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In most cases the one hour level modelling of the heating energy usage is detailed enough for understanding and interpreting the pattern of heating energy consumption. Quite generally this is also the accuracy where data for mathematical modelling is generally available. In this study distant heating energy consumption is modelled in two buildings in Finland based on 2018 data. Two methods are applied, multiple linear regression analysis and artificial neural networks. Modelling is based on weather data and data related to building usage and conditions. Building usage is modelled mainly by "proxy" variables like categorical variables of time intervals and weekdays. Even though there are some missing variables, results represent somewhat robust outcomes. Explanation rates of the models are app. 96-97 % and pre and post conditions for modelling are somewhat satisfactory met. Study discusses pros and cons of applied modelling approaches and provides some suggestions for further modelling procedures. In practical outcomes results show that models can predict somewhat precisely the changes at one hour level energy consumption at least for 24hrs ahead. An interesting detail is that also wind conditions seem to play a role which could be worth to take account. Data models of existing heating energy consumption pave the way for smart energy system adoption and applications and results also raise a bundle of new questions for further studies.

Keywords: modelling, multiple regression analysis, artificial neural network, one hour level, data, weather, proxy

Thomas Licklederer is a research associate and PhD student at the Technical University of Munich. His work focuses on the management of cross-sectoral energy systems on a neighborhood scale. His research interests are mathematical modelling, optimization, and optimal control in smart energy systems.

A Thermohydraulic Model of Bidirectional Heat Networks with Prosumers

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An integral part of smart energy systems for the future are smart thermal grids with prosumers. They are characterized by bidirectional heat exchange between the prosumers. To facilitate this, a major challenge is the design of the infrastructure and the smart control of its decentralized actuators. Models in the literature describe the thermal and hydraulic network state. However, there is no approach including the hydraulic actuators and the heat transfer to the prosumers. This paper derives a holistic system representation that allows to investigate the relations between the control variables of such networks and their thermohydraulic steady-state. As a basis, an infrastructure concept is introduced. Mathematical graph representation, network analysis and balance equations are combined with variables for the flexible prosumer operating states and with common physical models for the key network components. Like this, an equation system is obtained for the outlet conditions at the prosumers depending on the network control variables. The relations are discussed in terms of solvability and complexity for two use cases: a) simulation of the system states for given control inputs and b) determining the necessary control inputs for desired system states (optimal control). It is shown why and where modifications of the derived model equations are necessary in order to apply them with common solvers for the investigated use cases. Finally, an exemplary simulation is performed.

Keywords: district heating, heat network, smart thermal grid, prosumer, bidirectional, thermohydraulic, model, network analysis, steady-state, simulation, optimal control, infrastructure, pump, control valve

Ms. Danica Maljković has a background in power engineering and energy economics with 15 years of experience in the energy sector. Her special interest is in district heating (technical/planning, feasibility and regulatory), renewable energy and energy efficiency.

Evaluation of energy efficiency measures in district heating systems with deep learning

Danica Maljkovic, Energy Institute Hrvoje Pozar; Bojana Dalbelo Basic, University of Zagreb, Faculty of Electrical Engineering and Computing

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The EU's Directive 2012/27/EU on energy efficiency (EED) sets mandatory obligation to each EU Member State to implement energy efficiency measures in all energy systems, district heating being one of them. In order to evaluate the effects of implemented measures various analysis have been made including implementing machine learning algorithms which showed significant improvement in accuracy compared to classical engineering methods. This research is based on the hypothesis that deep learning could provide even more accurate evaluation of the effects of certain energy efficiency measures in district heating systems due to its non-linearity and ability to recognise hidden patterns in consumer behaviour. The analysed data set consists of consumption data from approximately 20,000 final consumers. The deep neural networks provided higher accuracy in forecasting of consumption after the implementation of energy efficiency measures in comparison to machine methods of random forest and support vector machines thus are able to serve as a reliable evaluation tool of the effect of implementation of mandatory obligations from EED in the sector of district heating.

Keywords: district heating, deep learning, deep neural net, machine learning, energy efficiency

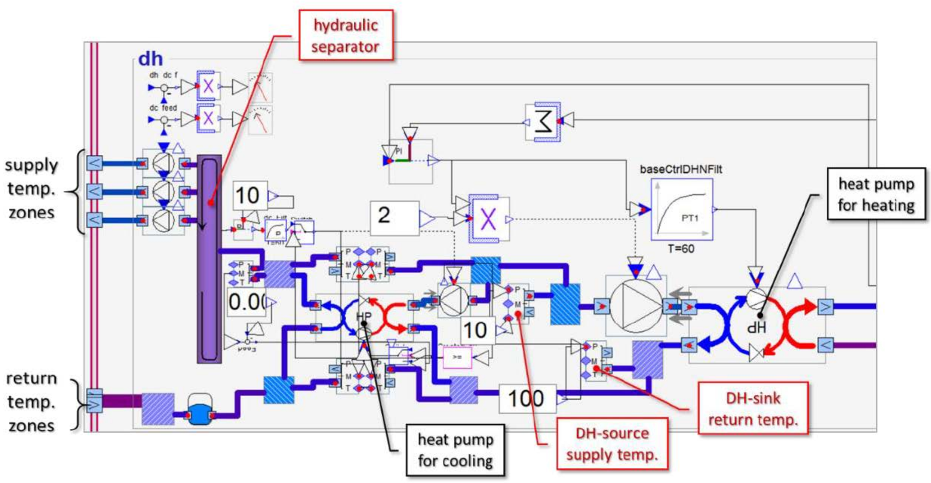

Figure 1: Automatable transfer station for coupling multiple thermal zones with a 5GDHC supply network including decentralised heat pumps for heating and cooling

David has a PhD from Aalborg University in Energy Planning. His main research interest is about the connection between urban planning and energy planning and how these can combine. His background is in technical energy system analysis and his research aims to understand how this can be best utilised in the energy transition in cities.

How scenarios can facilitate local energy planning in cities

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Cities have a high energy demand and are a substantial source of greenhouse gas emissions. Sustainable energy solutions (in energy conservation, energy efficiency, and renewable energy) can reduce energy demand and emissions. Integrating these solutions can lead to a decarbonised energy system. To understand and plan this system, planners can use energy system engineering scenarios and strategic energy planning. Furthermore, the transition to sustainable energy in cities is not only technical or economic but also social and involves numerous stakeholders and multiple levels of governance – thus forming an energy planning paradigm. This research asks how can sustainable energy scenarios facilitate the local energy planning paradigm? By applying a mixed-method approach, the research indicates that sustainable energy scenarios can facilitate the future energy planning paradigm by directing towards new planning approaches. Policymakers can implement dynamic approaches to policymaking. Integrated, holistic, and long-term scenarios can facilitate the selection of actions and measures and the development of strategies in cities. To strengthen this facilitation, further research about the engagement of stakeholders with energy scenarios is required.

Keywords: City, Sustainable, Renewable Energy, Climate Change, Modelling

Andrea Menapace is a Postdoc at the Free University of Bozen-Bolzano. He is an environmental engineer looking for efficient and sustainable solutions for water and energy distribution systems. His research areas are district heating , water supply systems and urban energy systems.

A flexible methodology to analyse 100 % renewable energy cities

Andrea Menapace, Free University of Bozen-Bolzano; Jakob Zinck Thellufsen, Aalborg University; Giovanni Pernigotto, Free University of Bozen-Bolzano; Andrea Gasparella, Free University of Bozen-Bolzano; Maurizio Righetti, Free University of Bozen-Bolzano; Marco Baratieri, Free University of Bozen-Bolzano; Henrik Lund, Aalborg University;

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This contribute proposes a methodology suitable for the design of 100 % renewable and smart energy cities for supporting the energy transition from current fossil fuel-based energy systems to future renewable-based systems. The presented design procedure relies on the criteria of local generation, smart flexibility, and sustainability. At this aim, the modelling of the urban energy scenarios adopts the holistic smart energy approach involving all energy sectors (i.e. heating, cooling, electricity, and transport) together with “connected island mode” operating conditions. This multi-step methodology consists of setting the actual energy system on the collected data, defining the business-as-usual scenario, implementing the structure of the smart energy system, analysing a large number of configurations among 100% renewable alternatives, selecting electricity balance systems and identifying the best solutions. The strengths of the proposed procedures lie in the robustness of the EnergyPLAN hourly energy systems simulation model able to simulate complex smart energy systems with the cutting-edge technologies, and in the flexibility of multiple criteria decision analysis allowing to study the best alternatives. The final result is a reliable methodology that supports the design of renewable cities through a deep multi-parameter analysis without setting a priori the target function, which allows great flexibility in the planning phase.

Keywords: Renewable Energy Cities, Energy Scenarios Modelling, EnergyPLAN, Smart Energy System, Renewable Energy

Evaluating the temperature performance of Danish building typologies in district heating networks

Martin Heine Kristensen, AffaldVarme Aarhus/Aarhus University; Lasse Sørensen, AffaldVarme Aarhus; Steffen Petersen, Aarhus University

Steffen Petersen (presenter)

District heating utilities divide the expenses of operating and maintaining their heating systems among the customers based on: 1) the size of the customers' substation, 2) how much heating the customers consume in a year, and 3) the efficiency at which the customers make use of the circulated water before returning it to the grid. The first and the second cost elements are easy to justify and quantify. However, evaluating the efficiency of individual customers and buildings, and quantifying how this affects the overall system efficiency is more difficult. Often, utilities measure the annually aggregated cooling temperature, or just the return temperature, of each customer substation. If the cooling temperature is too low, the customer is charged accordingly. If it is very high, the customer is fine and may even receive a bonus. However, this may not be entirely fair because different building typologies and their location in the grid have different prerequisites for utilizing the supplied energy.

In this contribution we present a statistical treatment of temperature data from more than 45 000 consumer meters. By segmenting the buildings into typologies and by accounting for the available supply temperatures, we present a comprehensive overview of the temperature conditions at the consumer as basis for discussing alternative ways of distributing the costs of operating the grid.

Keywords: district heating, smart meter data, hourly time series, building typologies, archetypes

Uni Reinert Petersen is a PhD Fellow at the Sustainable Energy Planning Research Group, in the Department of Planning, at Aalborg University.
The topic of Uni's research is methodologies for modelling 100% renewable energy systems at different scale, including continental, national and island-scale.

Pathways towards 100% renewable energy on the Faroe Islands

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Like most countries, The Faroe Islands are transitioning away from fossil fuels and towards renewable energy sources (RES). Located remotely in the middle of the Atlantic Ocean, the Faroes have abundant natural resources of wind, rainfall, tidal, and some solar. Nevertheless, the country is still heavily dependent on imported oil, making its economy vulnerable to volatile oil prices. In 2017, the country, with approximately 50.000 inhabitants, imported roughly 300.000 tonnes of oil. Half was used by marine vessels, while the remaining half was used onshore for heating, transportation, electricity, and industry. While most sectors rely solely on oil for energy, half of the electricity demand has in recent years been met by RES, hydro and wind, and there are concrete plans for increasing this share to 100% by 2030. However, the plans for addressing the fossil-fuel dependency of the remaining sectors are not as concrete, although their transition will inevitably impact the electricity sector. This paper argues that there is need for a more holistic perspective when addressing the transition towards RES on the Faroe Islands. To demonstrate this, the Faroe Islands' energy system is modelled in the Advanced Energy System Analysis Tool EnergyPLAN. Furthermore, with a Smart Energy Systems perspective, different 100% renewable scenarios are analysed, including a detailed study of the heating sector, identifying the potentials for heat savings, district heating and heat pumps.

Keywords: The Faroe Islands, the Faroes, Island energy systems, Remote energy systems, Isolated energy systems, Smart Energy Systems, Energy system modelling, 100% Renewable energy

Stefan Petrović received BSc and MSc degrees in electrical power systems from University of Belgrade in 2010 and 2012, respectively and PhD from Technical University of Denmark in 2017. Since then, he works as a Postdoc at the same institution and does research on energy system modelling and GIS.

An improved modelling of Danish district heating supply and demand in the future energy system

Diana Abad Hernando, Technical University of Denmark; Stefan Petrović, Technical University of Denmark; Ida Græsted Jensen, Technical University of Denmark; Russell McKenna, University of Aberdeen

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Previous studies showed that district heating should cover between 50 and 70% of the Danish heating demand. These studies are now around one decade old and many changes have since happened in the Danish and global energy systems. For example, the costs of wind, solar PV and solar heating decreased rapidly, data centres are now emerging as electricity consumers and excess heat sources, while renewable energy targets have been introduced. The present paper will improve the results of previous studies and describe the role of district heating in the future Danish energy system until 2050. We will apply rolling horizon approach within the open-source energy system model Balmorel. For the present analysis we have altered the standard Balmorel version by introducing seasonal COPs of heat pumps and endogenous heat savings in building stock and district heating expansion, differentiating district heating networks by geographical location, size and type, etc. The model changes are also applied to the future, for example reduced network losses and increased COPs of large-scale heat pumps. The results will show the cost-optimal mix and spatial distribution of heat savings, district heating (including expansion) and individual heat supply options. We will compare the total heating demands, district heating coverage and its production mix with previous studies and discuss whether the differences occur due to governmental policies, technological development or from the improved modelling.

Keywords: Heat savings, grid expansion, seasonal COPs, energy transition, Balmorel

Marianna Pozzi has recently graduated in Energy Engineering at Politecnico di Milano. She collaborates with the research group ReLAB of Politecnico di Milano about the simulation of consumption for heating and cooling in buildings under decarbonization scenarios.

A transparent assessment of retrofit potential in Italy based on open data

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The goal of this work is to present a statistical model for the estimation of energy demand of existing buildings and of the energy saving potentials of refurbishment scenarios, using Italy as a case study. The model is based on the analysis of two open data referring to the Italian Buildings Census, ISTAT, and the Energy Performance Certifications (EPC), required by 2010/31/CE directive. The correlation built between the heating demand and the chosen clusters, type of buildings and construction age, allows to characterize the spatial distribution of energy demand density with a high level of detail. The model is built and validated for the residential sector of Milano and it has been extended to the service sector and to the whole national census sections. The strength of this model is its ability to estimate the energy demand also where EPC are not available and to evaluate different penetration of retrofit scenarios, considering buildings characteristics and the chosen intervention. The application of the elaborated model to Milano as a case study has shown that the refurbishment could focus on the buildings with the worst energy performances: results have shown that the heating energy consumption could be reduced by 22-34 %, corresponding to refurbishment of only the 20-35% of the buildings but with the worst energy performance according to cost-benefit criteria. The sole envelope insulation could allow the major savings between 16-20 %.

Keywords: open data, retrofit, heating energy consumption, spatial distribution

Matteo Giacomo Prina hold a PhD in energy engineering. He has worked at EURAC research, institute for renewable energy, within the regional energy modelling group since 2014. His expertise varies from the development of algorithms for energy system modelling to data analysis and visualization.

Optimization method to obtain marginal abatement cost-curve through EnergyPLAN software

Matteo Giacomo Prina, EURAC Research; Fabio Capogna Fornaroli, Politecnico di Milano; David Moser,EURAC Research; Giampaolo Manzolini, Politecnico di Milano; Wolfram Sparber, EURAC Research;

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To face environmental and energy security issues, planning an energy system with high penetration of renewables is becoming increasingly important. The scope of energy system modelling is to support policy-makers in the definition of an energy strategy. Energy system models provide the best set of technologies to be implemented in a certain energy system. However, they do not give any information on the sequential order in which the investments of expansion capacity need to be done. Marginal abatement cost-curve is a method to provide this useful information to the policy-makers. Marginal abatement cost-curve are usually realized through a manual expert-driven approach. There are studies which implement an optimization process to achieve them. However, these studies usually reduce the time resolution in the modelling or do not consider a sector-coupling approach between the energy sectors. This, as demonstrated by different studies, increase the generation mix error. The aim of this paper is to realize an optimization method to obtain marginal abatement cost-curve without turning down the resolution in time or in sector-coupling. In order to achieve this scope, an optimization algorithm has been built over the EnergyPLAN software. The results are shown through the application of the model to the Italian energy system.

Keywords: Energy scenarios, Photovoltaics, EnergyPLAN, Optimization, Emissions, Cost-optimality, MAC curve

Dr. Diego Viesi (male) is a researcher of Fondazione Bruno Kessler (Italy) since 2013, working in the energy department. He has strong expertise in Smart Energy Systems, optimized energy scenarios (EnergyPLAN+MOEA) and energy policies.

A cost-optimized approach in regional decarbonisation: the integrated and dynamic energy modelling of the Province of Trento (Italy)

Diego Viesi, Fondazione Bruno Kessler; Luigi Crema, Fondazione Bruno Kessler; Md Shahriar Mahbub, Ahsanullah Univeristy of Science & Technology; Sara Verones, Provincia Autonoma di Trento; Roberto Brunelli, Provincia Autonoma di Trento; Paolo Baggio, Università degli Studi di Trento; Maurizio Fauri, Università degli Studi di Trento; Alessandro Prada, Università degli Studi di Trento; Andrea Bello, Università degli Studi di Trento; Benedetta Nodari, Università degli Studi di Trento; Silvia Silvestri, Fondazione Edmund Mach; Luca Tomasi, Fondazione Edmund Mach

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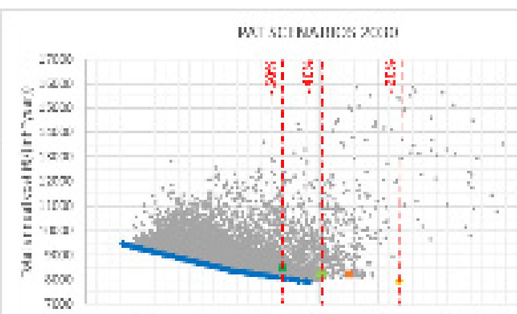
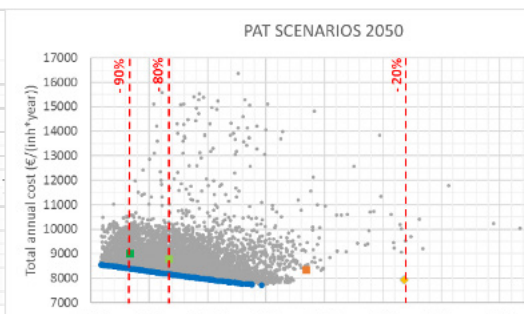
Regions have an important role in the European Union decarbonisation, designing tailor-made plans that consider local energy demands and available renewable energy sources as well as the potential of energy efficiency improvements while factoring in the social and economic context. In designing future scenarios dynamic synergies among all the energy sectors need to be exploited to develop new forms of flexibility. Moreover, reducing CO2 emissions while also minimizing energy costs is a complex challenge which requires a wide analysis of several energy scenarios. To address the problem, Mahbub et al. in 2016 first conceived the innovative integration of the EnergyPLAN software with a multi-objective evolutionary algorithm (MOEA). This work tests the EnergyPLAN+MOEA tool in the case study of the Province of Trento (Italy), where a new Provincial Energy-Environmental Plan, for the 2020-2050 period, has to be designed by a dedicated working group, composed of policy makers and researchers, on the base of optimal decarbonising solutions. A total of 30,000 scenarios are analysed, identifying as a key message the strategic role of sector coupling among large hydroelectric production, electrification of the thermal demand through heat pumps and of the transport demand through electric mobility. Finally, in a comparison with the Baseline 2016, a deep decarbonisation results achievable with slight increases in total annual cost, up to 14% for a -90% of CO2 emissions in 2050.
Keywords: integrated energy system modelling, multi-objective evolutionary algorithms, sector coupling, renewable energy, low-carbon economy

Fan Zhang received his master degree in knowledge engineering from National University of Singapore in 2016, worked in the field of building energy consumption data analysis and artificial intelligence. Now, he is pursuing a phd in the area of fault detection of district heating systems.

Night Setback Identification of District Heat Substations using Bidirectional Long Short Term Memory with Attention Mechanism

Fan Zhang, Departments of Microdata Analysis and Energy Technology Dalarna University, Chris Bales, Energy Technology Dalarna University, Hasan Fleyeh, Microdata Analysis Dalarna University

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District heating systems that distribute heat through pipelines to residential and commercial buildings have been widely used in Northern Europe and according to the latest study, district heating has the largest share of the heat supply market in Sweden. Therefore, energy efficiency of district heating systems is of great interest to energy stakeholders. However, it is not uncommon that district heating systems fail to achieve the expected performance due to various faults or inappropriate operations. Night setback is one control strategy that has been proved to be not a suitable setting for well insulated modern buildings in terms of both economic factor and energy efficiency. Especially, night setback leads to a sudden morning peak that can be problematic to utility companies. However, studies with respect to night setback identification are scarce in the literature. In this study, a new bidirectional long short term memory neural network based approach with attention mechanism is proposed for classifying night setback heat load of district heating substations. To evaluate the effectiveness of the proposed approach, data of 10 anonymous substations in Sweden are used in the case study. Precision, recall, and f1 score are used as performance measures. Results of out of sample testing show that the proposed approach outperforms the baseline models in this study. In addition, results show that by applying the attention mechanism, standard deviation of the model is reduced.

Keywords: District heating system, Deep learning, Artificial intelligence, Load pattern analysis, Machine learning, Attention algorithm

Theofanis Benakopoulos is a PhD student at the Department of Civil Engineering at Technical University of Denmark, focused on improving the operation of heating systems in existing buildings to provide the low-temperature operation conditions that will realize the Low-Temperature District Heating.

Faults detection and low operating temperatures in radiator system by using data from existing digital heat cost allocators in a multi-family building

Theofanis Benakopoulos, Technical University of Denmark & VITO NV; Robbe Salenbien, VITO NV; Michele Tunzi, Technical University of Denmark; Svend Svendsen, Technical University of Denmark

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The transition towards to LTDH requires a low temperature operation of the heating systems in existing buildings. The most common heating system in existing buildings is the radiator system. This low temperature operation is obstructed by the inefficient control of the heating system centrally in combination with the non-ideal local control by the users, such as the use of only few of the available radiators to provide the necessary thermal comfort in the apartment level. This requires a higher supply temperature and results in a high return temperature. This article aims to investigate the potential of lowering the operating temperatures of the heating system by using all the available radiators in each apartment. By using data from the existing electronic heat cost allocators the number of the radiators not being used can be detected. The measurements were used in the thermal/hydraulic model of the heating system to calculate the necessary operating temperatures with the actual number of radiator being used compared to all radiators being used. The calculations showed that an energy weighted average supply and return temperature of 44 and 30 respectively can be achieved when all radiators are being used. The reduction of the average operating temperature when all radiators are being used compared to a case where only half of the radiators being used was up to 10 .

Keywords: low-temperature district heating, radiator system, low return temperature, heat cost allocators, faults detection

Tom Burton studied chemical engineering at the University of Cambridge and joined the FairHeat graduate scheme in 2018. His research and professional work focuses on improving the performance of UK heat networks both at design and operational level.

Techno-economic assessment of external HIU cupboards on low temperature heat networks

Tom Burton, FairHeat ; Michael Ridge, FairHeat; Tom Naughton, FairHeat

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The UK norm is for dwelling substations (HIUs) to be located within dwellings. This limits access, which is an impediment to performance, as heat network operators are responsible for substation performance. In addition, single risers with long laterals are prevalent in the UK, which negatively impacts capital costs and network losses.

An alternative solution is to locate HIUs in externally accessible cupboards, ideally supplied directly off a riser with no lateral pipework. In addition to reducing cost of servicing and network losses, this also removes the risk of high pressure pipework in dwellings, reducing the requirement for hydraulic breaks and permitting a reduction in flow temperature. However, given the UK sales model, this approach reduces property sales revenue as it reduces the net internal dwelling area.

A techno-economic assessment has shown that, over a 30-year network lifespan, the CAPEX and OPEX benefits of external HIUs outweigh the reduction in revenue in all but the most expensive London locations. External HIUs with multiple risers enable pipework length to be reduced by c. 65% compared to single riser, internal HIU networks. Furthermore, this permits flow temperatures of 55°C, even for high rise apartment blocks. When combined with a top of riser keep warm strategy, this enables heat losses to be reduced by 60-70%, to approximately 40 W/dwelling. This strategy is now being adopted by a number of UK developers and housing associations.

Keywords: Low temperature heat networks, techno-economic assessment, UK, optimization, heat losses

Michel Gross, studied mechanical engineering with a focus on energy and process engineering at the Ruhr University Bochum (RUB). Since 2017 he is a research assistant at the Chair of Energy Systems and Energy Economics at the RUB and is developing concepts for innovativ district heating solutions.

Model based analysis of future district heating networks

Michel Gross, Department of Energy Technology Ruhr-University Bochum; Babak Karbasi, Department of Energy Technology Ruhr-University Bochum; Lisa Altieri, Department of Energy Technology Ruhr-University Bochum; Tobias Reiners, Department of Energy Technology Ruhr-University Bochum

Michel Gross (presenter) michel.gross@rub.de

This study investigates the performance of three different heating system scenarios for a new housing district in Germany. Low (60 °C) and ultra-low (20 °C) network temperatures are investigated as well as heat demand coverage possibility through a bidirectional network. The low temperature refers to the 4th generation networks, and the ultra-low temperature ones refer to the 5th generation network. The case study contains about 100 different single-family houses and multi-family residentials. Both space heating and domestic hot water are investigated on an hourly basis. The basic scenario is a network with a supply temperature of 60 °C. The second scenario is a network with 20 °C supply temperature and the third scenario is similar to the second scenario expanded by prosumers and a bidirectional network. In the third scenario solar collectors and a supermarket are investigated as decentral prosumers who supply heat to the network in times of surplus. Based on principles of graph theory a combined hydraulic and thermal model is developed and used for this study. The results show a heat loss reduction in the 5th generation networks due to lower network working temperatures (20 °C) of about 80 %. The implementation of prosumers significantly reduces the demand from a central heat source. About 20 % of the total heating demand can be covered by exceed heat of prosumer supply.

Keywords: 4GDH, 5GDH, Low Temperature district heating, Ultra Low temperature district heating, bidirectional network, prosumer, decentral heat pumps, case study

Oddgeir Gudmundsson has a PhD from University of Iceland. He has worked with district energy at a global level at Danfoss since 2012.

Central heat plant vs decentral temperature boosting in district heating

Oddgeir Gudmundsson, Danfoss A/S - Heating Segment - Application & Technology;
Jan Eric Thorsen, Danfoss A/S - Heating Segment - Application & Technology.

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With the success of the 4th generation district heating the sector has started to look further, what could be the next big change in the district heating sector. A proposal for the 5th generation district heating is ambient loops, which are classified as very low temperature supply which requires decentral temperature boost, via direct electric heating or heat pumps, for fulfilling both space heating and domestic hot water purposes. The question however remains if the ambient loop is economically favorable development or not compared to the 4th generation district heating. This presentation will focus on an economic comparison between these two competing solutions. The comparison is based on a mixed area of multi apartment buildings and row houses in London, with total 9.500 households connected. The presumption is that there is an available ambient heat source, with temperature range from 10°C to 45°C, which will require either central or decentral temperature boosting for fulfilling the heating demand. The results indicate that the cost optimal choice in this case would be 4th generation district heating.

Keywords: district energy, heating, cooling, heat pumps, ambient loop

Mengting Jiang received her master's degree in mechanical engineering from Delft University of Technology in 2018 and started working as a PhD researcher on the topic of flexible design and operation of future 4th generation district heating networks from 2019

A data-driven approach for fast and accurate dynamic simulation of district heating networks

Mengting Jiang, Eindhoven University of Technology; Camilo Rindt, Eindhoven University of Technology; David Smeulders, Eindhoven University of Technology;

Mengting Jiang (presenter) m.jiang1@tue.nl

In the transition towards a sustainable energy provision, the 4th generation district heating (4GDH) system is considered to be one of the most efficient approaches towards higher energy efficiency and the inclusion of renewable energy sources. A 4GDH system is typically characterized by low operation temperature levels, low temperature differences, intermittent operation and high fluctuation in supply temperature. These features lead to a need for highly accurate dynamic models that can be used to optimize the design and operation of the system. However, since DH systems usually contain many distribution pipes and end-users, detailed dynamic simulation for such complex systems becomes difficult. In order to include the dynamic characteristics of DH systems with feasible computational cost, a data-driven approach is proposed to calculate the dynamic behavior of all heat flows in the pipelines of the system. High-fidelity simulation results from separate detailed finite-difference calculations are used to obtain the unknown parameters in our data-driven model. A Recurrent Neural Network model, which includes a feedback connection to allow time sequence simulation, is used to capture the dynamic behavior of the system. By increasing the computational efficiency of the pipeline calculations, the total computational time of the system simulations is significantly decreased without losing accuracy. The application of this new model is not limited by the topology of the DH system.

Keywords: Dynamic Simulation, Data-driven Approach, District Heating System

Gareth Jones is Managing Director of FairHeat, a specialist heat network consultancy in the UK. Gareth is Chair of the BESA UK HIU Test Standard, Vice Chair of the ADE Heat Networks Forum and is on the steering committee for the ADE CIBSE Heat Networks Code of Practice.

Acceptance Testing: Improvement of network performance through standardised dwelling test regime

Gareth Jones, FairHeat Ltd

Gareth Jones (presenter) gareth.jones@fairheat.com

An assessment of UK residential heat network performance was carried out as part of UK government funded research from 2015 through 2017. This research highlighted a significant gap between potential performance and realised performance for 30 UK heat networks. Of this performance gap, c.60% was due to design issues, with c.40% due to issues with commissioning at handover. Further investigation identified that most of the commissioning related issues derived from poor commissioning at a dwelling level, primarily at the point of handover. In order to improve dwelling level commissioning, a set of performance KPIs were developed, along with a testing methodology and testing procedures for new build residential developments. By involving design consultants, building developers and M&E contractors, this “Acceptance Testing” process has now become incorporated into the overall build process for a significant subset of UK private developers and social housing organisations, with over 4,500 new build dwellings tested to date across 35 developments. For developments where Acceptance Testing has been carried out in 100% of dwellings, the performance gap has been reduced or eliminated entirely, with many developments performing better than design. A number of developments are now operating with peak return temperatures consistently <30°C across the year. Acceptance Testing is now incorporated into the UK Heat Networks Code of Practice (“CP1”), which sets standards for the industry.

Keywords: Performance Testing, Heat Networks, Performance Gap

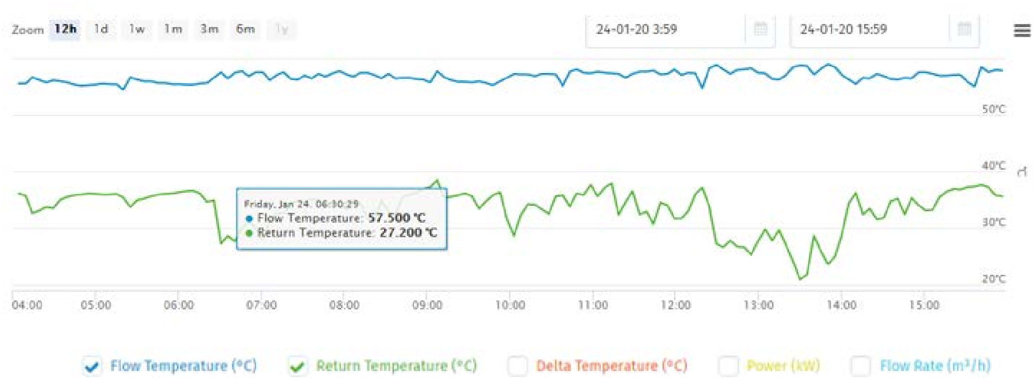

Figure: Typical Flow and Return Temperature for North London Heat Network post Acceptance Testing, 24/01/2020

Mathias Kersten is a post graduate research assistant working at Technische Universität Berlin in the research field of Building Energy Engineering.

Emission reduction in 4th generation district heat supply networks

Mathias Kersten, Technische Universität Berlin; Max Bachmann, Technische Universität Berlin; Prof. Dr.-Ing. Martin Kriegel, Technische Universität Berlin;

Dipl.-Ing. Mathias Kersten (presenter) mathias.kersten@tu-berlin.de

To lower greenhouse gas emissions in the building sector new concepts for heat supply networks are necessary. A static approach using the annual load duration curve is not suitable due to fluctuation of renewable sources and complex funding regulations. To develop a feasible heat supply concept a tool based on the open source software oemof is developed. Goal of the study is to develop a concept for an economically optimal pool of heat producing units which satisfies given emission and technology constraints. An hourly database of heat demand and renewable sources is considered. A detailed concept of a pool of heat producers for the model region is developed. Fulfilling the given constraints, a maximum emission reduction of 90% compared to the actual state situation is possible. The economically optimal pool of heat producing units for the model region results in emission reduction of 50%. Absolute capacities of heat producing units and storages were calculated. The relative share of producer capacities was as expected. The results include a basic concept of the system control requirements which in further steps can be elaborated. A variety of emission reduction scenarios with suitable cost of heat production was calculated. The developed concepts for the model region make goals for emission reduction in the heat supply sector achievable with suitable levelized cost of heat production. The developed planning tool is applicable or adaptable for various regions and constraints.

Keywords: heat supply network, emission reduction, renewable energy, funding regulations, planning tool, oemof

Igor Krupenski is the head of heat, cooling and gas supply systems designing company and lector in the Department of Energy Technology, Tallinn University of Technology(TalTech). His field of research interest are smart energy systems: gas, district heating and district cooling systems.

District cooling system operation in cold climates with existing district heating networks

Igor Krupenski, HeatConsult OÜ, Tallinn University of Technology; Henrik Pieper, Tallinn University of Technology; Aleksandr *Ledvanov, HeatConsult* OÜ; Lina *Murauskaite, Lithuanian Energy Institute; Anna Volkova, Tallinn University of Technology*

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District cooling (DC) is an important part of Smart Energy Systems. Due to the global trend of reducing heat loss in buildings, the proportion of cooling is on the rise. Considering the possibilities of free cooling and the use of waste heat in DC systems, a practical approach is needed to develop new DC networks. Tallinn has well-developed district heating (DH) networks in operation for over 60 years. Due to the numerous CHPs in the DH network, a large amount of heat is wasted. Existing clients of the DH network are used to outsourced energy supply, so there is a great potential for the development of DC in Tallinn. Study examines the potential for DC development in Tallinn's business district of Ülemiste City and provides a practical approach to DC development. Ülemiste City is a business district with an existing developed area of 160 000 m2. Existing buildings, mainly office buildings and several shopping malls, are heated by gas heating and cooled by conventional electrical cooling. According to the master plan of the area, an additional 600 000 m2 of land will be developed in the next 10 years. This study analyses the possibility of developing a DC network in the area, both for new and existing buildings. An analysis of the following sources and their combinations are provided: absorption chillers using waste heat from CHP plants, free cooling from the nearest lakes, and conventional electric chillers covering peak loads.

Keywords: smart city, district cooling, waste heat, free cooling

DESTOSIMKAFE – Development & Rating of Technical & Organizational System Solutions For Cold District Heating to Supply Heating and Cooling

Lorenz Leppin, AEE Intec; Harald Schrammel, AEE Intec; Ingo Leusbrock, AEE Intec; Michael Salzmann, AEE Intec

Ingo Leusbrock (presenter) l.leppin@aee.at

This abstract gives an overview of the research work on a novel concept of grid-based heating and cooling in the form of cold district heating networks (CDH). The declared aim of the project is to improve the usability of an innovative and sustainable heating and cooling supply based on CDHC concepts by collecting and merging national and international know-how and practical experience. To demonstrate the applicability and feasibility of innovative and sustainable heating and cooling supply on the basis of CDH, complex technical system solutions and methodical as well as simulation-technical basics for the conception, planning and long-term evaluation of such systems are developed. This is followed by developing a stochastic model for the long-term evaluation of system solutions based on varying framework conditions and exogenous scenarios is being developed. Based on those system solutions and the technical/ecological evaluation, tailor-made products and services for CDH will be developed, which will then be incorporated into an economic evaluation method. It could be shown that due to the low operating temperature of the anergy network a multitude of renewable heat sources can be implemented in the overall energy mix of the grid. The successful implementation of an anergy network in a respective area, quarter or district depends on the boundary conditions in which it is set up. Available cheap waste heat source close-by can help lower the over-all investment.

Keywords: cold district heating networks, decarbonisation, anergy, waste heat source, heat loss reduction, power-to-heat, sector coupling

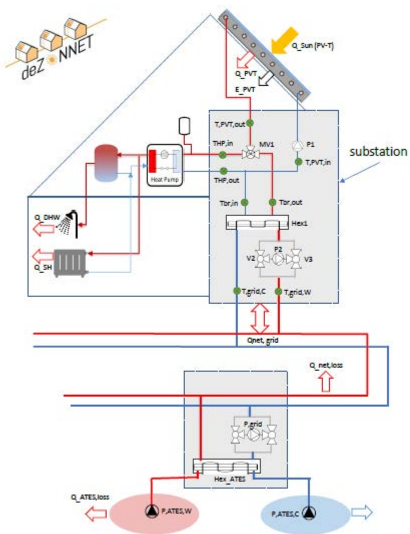
Acknowledgement: The project has received funding from the Austrian Research Promotion Agency (FFG), project number 865010

Robust thermo-hydraulic design of prosumer district heating networks

Lefki Loverdou, department H2I, Deltares, Delft, Netherlands;
Ivo Pothof, department Process & Energy, TUDelft, Delft, Netherlands / H2I, Deltares, Netherlands;

This paper presents an approach for the robust thermo-hydraulic design a ULTDH prosumer network. The novelty of this paper is the design approach of the control systems to obtain a robust and stable control of the substations and the ULTDH network. Every house is equipped with a PVT, a water/water heat pump and a local circulation pump at the grid side of the substation. The individual house heat-pumps are boosting the temperature of the PVT and/or grid outlet. Representative yearly timeseries of expected thermal energy production depending on the house location, roof orientation and weather predictions are used. The yearly thermal energy demand is based on the available information of the insulation level of the actual neighborhood houses. The network operates at similar pressures (3 barg) in the warm and cold lines. The substation circulation pump is installed in a Wheatstone bridge to enable heat supply and return heat from the PVT panels. The design distribution temperatures are 18/11oC in summer and 14/7oC in winter. The substation design is outlined in this paper. Furthermore, we will present the control system design at the substation and the ATES circulation pumps and outline the dynamic scenarios to verify the stable operation of the substations and entire prosumer network. This design approach for prosumer substations is generic and thus suitable for similar prosumer networks. Results will be illustrated with the case study of Ramplaankwartier in the Netherlands.

Keywords: Ultra low temperature district heating, prosumer networks, heat losses, photovoltaic thermal panels, PI control, ATES, WANDA.



Graeme Maidment is a professor of Heating and Cooling. Co-lead of Mission Innovation Challenge 7 - Affordable Heating and Cooling of Buildings

Exploring 5th Generation Integrated energy systems

Akos Revesz London South Bank University
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The uptake of renewables is resulting in large reductions in grid carbon intensity with increasing amounts of intermittent renewables on the grid, a progressive move to electric vehicles and increasing peak load on the network is making the balancing of generation and demand more difficult. This challenge can be mitigated by operating energy assets flexibly. Heating and cooling assets have significant flexibility which can be exploited using advanced ICT to deliver significant carbon reductions.

Heating and cooling assets can be controlled individually or can form part of a smart network. By integrating into 5th generation low temperature heat networks it's possible to deliver further carbon savings, since heat can be shared between heating and cooling applications and heat from renewable or secondary heat sources (such as substations or ventilation shafts) can be captured.

Lot-NET is a 5 year project which investigates how 5G networks combine with heat pump and storage technologies to meet the energy needs of buildings, whilst connecting to renewable and secondary heat sources. Whilst, the principles of integrated smart energy systems has been well described, there is limited consolidated information on the application of these energy systems. Lot-NET has identified sister projects, many with different levels of complexity and application. The purpose of this paper is to start to bring together and introduce a survey that will gain better understanding.

Keywords: 5th generation, smart heating and cooling, heat power mobility, heat networks

Sara Månsson is a Ph.D. student at the Department of Energy Sciences at Lund University, Sweden. The focus of the research is to identify and handle issues in the DH systems by combining results from data analytics with knowledge of DH substations, system operation, and buildings.

A taxonomy for labelling deviations in district heating systems

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District heating (DH) systems of today contain a number of issues, or faults, that cause deviating patterns in data collected in the DH systems. Up until now, there has been no unanimous approach in the DH utilities to label faults causing deviations, which complicates the development of automatic fault detection and diagnosis (FDD) algorithms. This study aims to propose such a taxonomy for labelling deviations, creating value for DH utilities in current and future DH systems. The basic structure of the deviation cause taxonomy was based on literature studies, workshops and discussions with partners within Swedish FutureHeat project Smart Energi. Once the basic structure was decided, it was sent out for evaluation amongst Swedish DH utilities. The evaluation was carried out as a survey study, in combination with a number of qualitative interviews. The results from the survey and interview studies were compiled and the finalized version of the deviation code taxonomy was produced. The study includes the results of the survey and interview studies, as well as the finalized version of the deviation cause taxonomy. The proposed structure serves two main purposes: 1. Provides a simple and efficient way for DH utilities to register faults, and 2. Provides possibility to create harmonized, labelled data sets that may be used to develop methods for automatic FDD in DH systems. This will be valuable in many different applications in current and future DH systems.

Keywords: Deviation labelling, DH data, Fault labelling, Fault detection and diagnosis, Taxonomy

Since 2015, Thomas Naughton has led the operations team at the award-winning FairHeat consultancy. He champions low-temperature district heating within the UK built environment and has contributed to many industry leading initiatives.

Process for optimising heat network performance of existing buildings in the UK

Thomas Naughton, FairHeat

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Heat networks are a vital component of the UK's policy for the decarbonisation of heat. The proportion of heat demand met by heat networks is expected to increase from 2% in 2020 to 18% in 2050. Significant steps are being taken to ensure that new networks perform well. At the same time, the UK recognises that there are 500k customers on legacy networks that can't be left behind and that improving the performance of existing residential communal heating systems prior to connection to larger district heating systems will be critical. FairHeat have developed an optimisation process based on analysis of high-frequency data and root cause analysis that delivers large reductions in operating temperatures and resident comfort. The process has been used to significantly improve the performance of many residential heat networks. One example is the conversion of an 80C/60C (flow/return) heat network in a communal heating system in London to a 65/40C system. The interventions also resulted in a decrease in electricity consumption and increase in resident satisfaction. Working in collaboration with the UK government, FairHeat has recently employed the process on ten communal heating systems across private and social housing. The output of the research is to increase understanding among heat network operators with respect to developing the business case for addressing sub-optimal performance, improving the customer experience and to reduce the risk to heat network growth in the UK.

Keywords: Residential, low temperature heat networks, performance optimisation

Pavel Rušeljuk is graduated from Tallinn University of Technology in the field of Thermal Engineering and is the head of DH operating company. His field of research interests is related to district heating, heat generation and CHP.

Economic Dispatch of District Heating Networks via Consumption-Based Management

Pavel Rušeljuk, Narva Soojusvõrk; Kertu Lepiksaar, Tallinn University of Technology; Andres Siirde, Tallinn University of Technology; Eduard Latõšov, Tallinn University of Technology; Anna Volkova, Tallinn University of Technology

Pavel Rušeljuk (presenter) Pavel.Ruseljuk@energia.ee

All components of District Heating Networks, i.e., generation, transportation, distribution and heat consumption have a great potential for energy savings. The competitiveness of thermal energy in the market largely depends on the temperature of the return network water. Consumption-based management makes it possible to give recommendations on reducing heat consumption based on demand response and heating unit operation, as well as significantly increase energy efficiency of the production processes and reduce heat consumption, primary energy consumption and CO2 emissions. Optimisation and management of heating networks is a very complex issue with a variety of technical, economic and environmental aspects. Optimisation of heat load profiles of district heating networks is necessary to smooth the peak of heat consumption and improve network efficiency. Economic Dispatch is necessary to predict the consumption of the network, so we considered various stages of optimisation: production model, energy supply network model, nodes model, and consumer model. The goal is to save primary energy by optimising each participant in the process as part of the overall optimization. In this study, it is necessary to indicate the various types of participants and the corresponding optima, which requires a general extensive study of the heat supply market.

Keywords: Economic dispatch, consumers, district heating, remote metering

Costanza Saletti is a PhD student in Industrial Engineering at the Department of Engineering and Architecture of the University of Parma. Her research interests are related to the simulation, optimization and advanced control of complex energy systems and district heating and cooling networks.

Enabling smart control by optimal management of the State of Charge of district heating networks

Costanza Saletti, University of Parma; Nathan Zimmerman, Mälardalen University; Mirko Morini, University of Parma; Konstantinos Kyprianidis, Mälardalen University; Agostino Gambarotta, University of Parma

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District heating and cooling networks (DHC) have become widespread in several European countries due to their ability to distribute thermal energy efficiently, which leads to reduced carbon emissions and improved air quality, especially in populated areas. The characteristics of these networks varies remarkably depending on the urban layout and system dimensions. Moreover, extensive data about the energy distribution and thermal capacity of the different areas are hardly available in many regions. Hence, the system design and smart control can be challenging and time-consuming. This work aims to address this issue by proposing a novel approach to include the thermal capacity in the optimal control of large-scale DHC. Starting from coarse data available at the substations of the district heating network of the city of Västerås, Sweden, a physics-based model of the aggregated neighborhoods of the system is developed and validated. The model is used to estimate the aggregated thermal capacity of the connected users and, therefore, to define the neighborhood State of Charge, which is exploited to store or retrieve energy when it is convenient, while keeping the indoor thermal comfort. This concept is included in a Model Predictive Controller that optimizes the power plant management and thermal energy distribution. This procedure can be easily replicated to optimize systems of different sizes (from building- to city-scale) and to support their transition to 4th generation DHC.

Keywords: district heating and cooling networks; smart control; Model Predictive Control; optimization; optimal management; scalability; simulation platform; energy efficiency

Amos Schledorn is a research assistant at the Section of Dynamical Systems under the Department of Applied Mathematics and Computer Science of the Technical University of Denmark. His research focuses on the planning and operation of integrated energy systems under uncertainty.

An advanced optimization-based bidding method for district heating providers considering uncertainty and block bids

Amos Schledorn, Technical University of Denmark; Daniela Guericke, Technical University of Denmark; Anders Andersen, EMD International; Henrik Madsen, Technical University of Denmark

Amos Schledorn (presenter) amosc@dtu.dk

In Denmark, sector coupling through the electrification of district heating (DH) can make a significant contribution to achieve the flexibility in the energy system that is needed for the integration of renewable energy. For an efficient coupling of the heat and power sector, the increasingly complex DH systems need to optimize their operation and participate in power markets to reduce operational costs. In this work, we extend our basic Heat Unit Replacement Bidding (HURB) method that optimizes hourly day-ahead market bids for combined heat and power (CHP) units in DH using an iterative approach based on (mixed-integer) linear programming [1]. While the basic version relies on fully dispatchable production, we now propose a new version of the method that integrates further types of production such as uncertain production from solar units and power- to-heat units. Furthermore, we present advances on introducing more complex bidding structures in the form of block bids. We analyze our method and present results based on a realistic test case.
This work is funded by the Innovation Fund Denmark through the Centre for IT–Intelligent Energy Systems in cities (CITIES) (no. 1035-00027B) and the project Heat 4.0 - Digitally supported Smart District Heating (no. 8090- 00046B).

[1] Blanco, I., Andersen, A.N., Guericke, D., Madsen, H., A novel bidding method for combined heat and power units in district heating systems. Energy Syst (2019). https://doi.org/10.1007/s12667-019-00352-0

Keywords: District heating, bidding, block bids, electricity markets, optimization, inte- grated energy systems

Annette Steingrube studied mechanical engineering and has been working at Fraunhofer ISE for 6 years. Her research focus is the evaluation of future district heating networks as well as future urban energy systems and the integration of social and psychological factors into energy system models.

Transformation strategies to decarbonize district heating networks

Annette Steingrube, Fraunhofer Institute for Solar Energy Systems; Gerhard Stryi-Hipp, Fraunhofer Institute for Solar Energy Systems; Daniel Siejak, Fraunhofer Institute for Solar Energy Systems

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District heating networks (DHN) are important to decarbonize urban energy systems. However, the transformation of the today's high temperature DHN into efficient low temperature DHN is a prerequisite to enable the integration of renewable and waste energy sources. Secondly, DHN must be adapted to a decreasing heat demand due to energetic refurbishment of buildings. Thirdly, DHN should provide in the future flexibilities to the energy system by sector coupling. To review the opportunities of a DHN transformation in practice, the existing high temperature DHN of the district Weingarten in Freiburg, Germany with a supply temperature up to 120 °C was examined. The performance of the central heating station and of the connected buildings was measured and the heat supply system was modelled with Dymola. This allowed the simulation of the impact of a lower heating demand in the district and of a reduced supply temperature of the grid to 70 °C, respectively 40 °C. Furthermore, the integration of decentral generated solar heat with local thermal storages and a supply temperature of 70 °C was analyzed. In the last scenario the inclusion of central generated solar heat with a supply temperature of 40 °C and heat pumps for DHW was evaluated. All options for the transformation of the DHN are compared regarding their efficiency improvements, their adaptability on reduced heat demand, the ability to integrate climate neutral energy sources and the related costs.

Keywords: District heating network, decarbonization, transformation strategy, low temperature district heating network, solar heat, simulation

Tim Taylor has 20 years of experience in the UK clean tech industry from CHP, biomass to district heating. He encompasses a full portfolio of industry experience from problem solving on site to mechanical design installation through to heat mapping and master-planning.

Case study of a 3rd gen CHP district heating system that got updated to a 5th gen system with a shared ground source heat pump system

Tim Taylor, Sweco UK Limited, MCIBSE (Application Pending)

Tim Taylor (presenter)

Most UK district heating networks are 3rd generation systems where primary operating temperatures sit between 90°C to 70°C circulating this through a network of per-insulated pipes.

Although 3rd gen delivers carbon savings it comes with higher conductive heat loses when compared to 4th or 5th gen systems where primary temperatures are closer to ambient. This allows extra heat sources between 90°C and 15°C to input energy into the network that would otherwise be dumped to atmosphere. Heat pumps are then installed in each building to raise the secondary temperatures to suit thermal needs.

Sweco reviewed a 2017 DHN study of a centralised energy centre with gas CHP, an alternative design was put forward for a 5th gen system using a ground source water as the primary heating medium. The review showed that by jumping a generation it had advantages of :-

- Reduced conductive losses.
- Heat recovery from air conditioning units,
- Heating and / or cooling available from a single source,
- No combustion equipment for heating reducing localised air emissions,
- Smaller energy centre building,
- Thermal demands supplied from a renewable electricity tariff.
- Enabled the local council to meet its 2040 carbon zero target.

Unfortunately, the design was not accepted due to concerns about technology cost, maturity and resilience of the system. Multiple lessons were learnt in moving the design from 3rd Gen to 5th Gen which can be shared with wider industry.

Keywords: Climate emergency, electrification of heat, CHP, centralised energy centre, ground source heat pumps, ambient loop, heat losses, flexibility, pump room, air, noise, thermal stores, availability.

Jan Eric Thorsen is director at the Danfoss Heating Segment Application Centre. This includes internal and external consultant focusing on energy systems, feasibility studies and related system and component development.

Experience with booster for DHW circulation in multi appartment building

Jan Eric Thorsen (*), Director Danfoss Heating Segment Application Centre
Svend Svendsen, Kevin Michael Smith, Technical University of Denmark, Department of civil engineering
Torben Ommen, Technical University of Denmark, Department of mechanical engineering.
Morten Skov, HOFOR, Greater Copenhagen District Heating Utility

Jan Eric Thorsen (presenter)

As part of the Energylab Nordhavn project, www.energylabnordhavn.dk, DTU, HOFOR and Danfoss have developed, assembled and installed a Circulation Booster (CB) in an old multifamily house located in Copenhagen. The purpose of the CB is to boost the domestic hot water (DHW) circulation temperature, and at the same time secure a low district heating (DH) return temperature from this part of the service. The DHW circulation temperature is boosted in two steps, by direct heat exchange and by a heat pump. The source of the CB is district heating. This presentation includes the authors' experiences from the 1-year field test period, the performance results regarding electric share and DH return temperatures as well as a simple economic feasibility study.
The authors have concluded that the CB is operating as intended. The share of electric energy for the DHW circulation part is 19.5%. The representative DH return temperature from the DHW circulation service (compensating for circulation heat loss) is 21.5°C, reduced from a level of 47.2°C.
The current tariff structure related to the DH return temperature rebate and electric costs gives a marginal feasible economic case for the CB concept. In case of a more progressive rebate scheme for providing a low DH return temperature or reduced electricity costs, the economic feasibility is quite favorable.

Keywords: DHW Circulation loss, Booster Station, Heat Pump, 4th Generation District Heating

Riccardo Toffanin holds a MSc. in Sustainable Energy Systems from KTH (Sweden) / UPC (Spain) and a BSc. in Energy Engineering from Politecnico di Milano (Italy). He works at MEMTi - DTI - SUPSI (Switzerland) focusing on the simulation of energy systems, and especially district heating networks.

Impact of Legionella regulation on a 4th generation district heating substation energy use and cost: the case of a Swiss single-family household

Riccardo Toffanin, MEMTi – DTI – SUPSI; Vinicio Curti, MEMTi – DTI – SUPSI / Calore SA; Maurizio C. Barbato, MEMTi – DTI – SUPSI.

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Fourth Generation District Heating (4GDH) systems can have a supply temperature lower than 50 °C to decrease losses and to favour the integration of renewable and waste heat. As the maximum water supply temperature requirement for space heating in most new and some retrofitted buildings is around 35 °C or lower, they would be suitable for 4GDH. However, an important obstacle for lower supply temperatures in district heating is domestic hot water (DHW) due to a high Legionella proliferation rate at temperatures between 20 – 55 °C. The most common solution is maintaining the temperature above the standard Legionella growing range, even if 40 – 45 °C would be sufficient for comfort. Nevertheless, in Europe the current regulation varies widely among countries, especially for small buildings. This paper aims to study the effect of different Legionella regulations on the DHW energy use, and on the substation investment and operating cost of a Swiss single-family household connected to a 4GDH network. The Swiss normative is confronted with the Danish regulation and the "3-litre rule" based on German standard W551. Detailed calculations in MATLAB/Simulink demonstrated that a relaxation of the current Swiss regulations could present energy and economic savings. The German "3-litre rule" resulted in an annual energy consumption reduction of 30%, and annual substation cost savings of 38%, while the Danish standard achieved the lowest subsidised investment cost.

Keywords: District heating, 4GDH, substation, DHW, Legionella, booster heat pump, single-family household

Ulrich Trabert is a PhD candidate at the Institute of Thermal Engineering at the University of Kassel, Germany. His current research comprises feasibility studies for innovative DH systems with a focus on optimised heat production and economic and ecological system evaluation.

Feasibility study and techno-economic evaluation of a DH integration of a river water heat pump at a CHP plant in Germany

Ulrich Trabert, University of Kassel; Isabelle Best, University of Kassel; Weena Bergsträßer, University of Kassel; Oleg Kusyy, University of Kassel; Janybek Orozaliev, University of Kassel; Klaus Vajen, University of Kassel;

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Heat for German district heating (DH) systems is primarily produced in combined heat and power (CHP) plants using fossil fuels like natural gas, hard coal and lignite as well as waste. A frequent feature of existing CHP systems with steam or gas turbines are (emergency) cooling systems using river water. The decarbonization of urban DH systems requires increased network efficiency in combination with the development of new heat sources like solar radiation and environmental heat. Existing infrastructure and permissions for river water usage at CHP plants are an excellent opportunity to integrate electric river water heat pumps into DH systems. In this work a feasibility study of such an application is conducted for an urban district with mainly residential and a few commercial buildings. The basis for the setup is a sub grid with lowered temperatures compared to its primary network. Long-term simulations (15 years) of heat production with energyPRO are used for the techno-economic evaluation of different designs. Dimensioning of heat production components is guided by the requirements of the German subsidy program "Wärmenetze 4.0". Within this framework, the effects of varying buffer storage sizes as well as electricity market price induced operation of heat production is assessed. The paper outlines how large river water heat pumps can contribute to enhance further integration of renewable energies into the electricity grid.

Keywords: river water heat pump, CHP plant, DH decarbonization, LCoH

Anna Vannahme obtained her M.Sc. degree from the TU Munich. Her research focusses on district heating systems in rural areas and their optimization possibilities. Her main research interests are the analysis of substations for single-family homes and innovative operating strategies.

Comparison of Different District Heating Substation-Systems in a Hardware-in-the-Loop-Test Rig

Anna Vannahme (M.Sc.), Jonas Busch (M.Sc.), Mathias Ehrenwirth (M.Eng.), Dr.-Ing. Tobias Schrag, Technische Hochschule Ingolstadt, Institute for new Energy Systems

Anna Vannahme (presenter) anna.vannahme@thi.de

In this ongoing project, strategies to reduce losses in rural small district heating networks (DHN) are analysed using the example of two existing biomass DHNs. The aim of the project is to improve DHN with low-investment measures. This should enable them to be operated cost-efficiently in the future. The main consumers in rural areas are often non-retrofitted detached houses. It is to be investigated whether the DHN temperatures can be reduced by optimizing the district heating substation (DHS). Typical DHS are the continuous-flow system (CFS) and the storage system (SS) (VDI, 2009; Euroheat & Power, 2008) (cf. Figure 1a and 1b). In order to reduce the DHN return temperatures, hydraulic optimizations of the already installed DHS are explored in a thermal Hardware-in-the-Loop-test rig. To lower supply temperatures on an annual average, also schedule-based operating strategies are examined (Euring, 2017; Leoni, 2018). To achieve this, the DHS will be upgraded with a controller that can communicate with the central control of the DHN. If there are no storages or the installed ones are too small, it will be determined whether it is economical to install another type of DHS, the so called Storage-DHS (SDHS) (cf. Figure 1c). The SDHS has not only the potential to reduce return temperatures but also to reduce the maximum load. The present study analyses a SDHS in comparison to a CFS.

Keywords: Thermal Hardware-in-the-Loop-Test Rig, District Heating Substation, Local District Heating Network, Non-Retrofitted Detached Houses

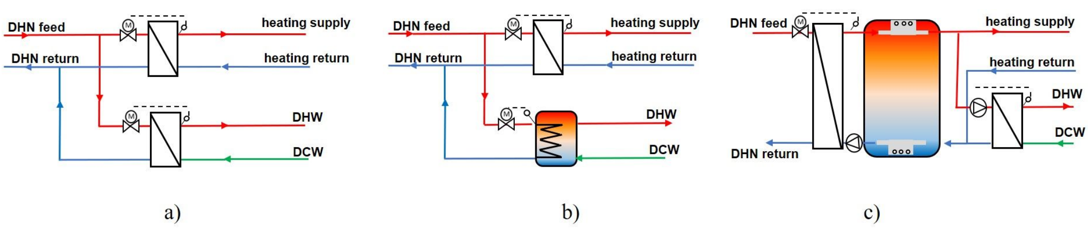

Figure 1: a) Continuous-flow system (CFS), b) Storage system (SS), c) Storage DHS (SDHS)

Yannic Wack is researching on the application of adjoint-based topology optimization methods to District Heating Network design.

Showcasing the potential of adjoint-based topology methods to optimize District Heating Network design on district level

Yannick Wack, KU Leuven, Flemish Institute for Technological Research (VITO), EnergyVille; Maarten Blommaert, KU Leuven, Flemish Institute for Technological Research (VITO), EnergyVille; Robbe Salenbien, Flemish Institute for Technological Research (VITO), EnergyVille; Martine Baelmans, KU Leuven, EnergyVille;

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Being able to integrate a variety of renewable and low-carbon energy sources, modern District Heating Networks are an important driver of the energy transition in the heating sector. To cope with the complexity of 4th generation District Heating Networks, their design and topology is commonly optimized using Mixed Integer Linear- and Nonlinear Programs (MILP & MINLP). To overcome the loss of detail intrinsic to MILP and the limits on the problem scale for MINLP, we present a new adjoint gradient based topology optimization approach to District Heating Network design. This approach minimizes the networks investment and operational cost while enforcing the satisfaction of the consumers heat demand, by tuning pipe placement and size, production design and the consumer control parameters. The optimization is based on a bottom-up district heating network model, describing conservation of mass momentum and energy within the network. The discrete nature of the network design variables is integrated in the optimization process by a numerical continuation strategy gradually driving the design towards discrete values. Combining the inherent scalability of the adjoint-based gradient evaluation with this continuation strategy enables the non-linear optimization of large scale District Heating Networks. We therefore demonstrate the capabilities of this approach on a case study for a district in Leuven.

Keywords: Optimal topology, Optimal design, District Heating Network, Adjoint-based optimization,

Sven Werner has been active in district heating since 1978. Sven has coordinated and participated in research projects concerning the future for district heating in Europe. He is a Co-author of textbooks about district heating and cooling. Retired in 2018 and now acting as professor emeritus, but still curious in the subject.

Vocabulary for fourth generation of district heating

Mattias Sulzer, EMPA, Switzerland; Sven Werner, Halmstad University, Sweden

Sven Werner (presenter) sven.werner@hh.se

Fourth generation of district heating (4GDH) is an established expression for new kinds of district heating and cooling systems that will be implemented during the coming years. The main goal is to develop a new technology generation that can substitute older technology generations that was originally developed for fossil fuels. The future conditions are in general lower heat demands and increased cooling demands supplied from renewable and recycled thermal sources. The new technology generation must consider these new conditions. The 4GDH technology will not be a monoculture with one dominant network configuration that will be used everywhere. Instead, several different configurations are foreseen. One important component in 4GDH will be the use of low-temperature thermal energy distribution, for heating, cooling or both. It is very important at this developing stage to consolidate all possible technical solutions into the 4GDH family. This is especially the case with cold distribution networks, since many new systems in Europe, North America, and Asia will use this network configuration for both heating and cooling purposes. This presentation will provide a suggestion for a harmonisation of expressions, terms, definitions, and network configurations that have been introduced and used during the last years, concerning 4GDH. This clarification is intended to provide a basis for a common language to support developments in the field of thermal networks internationally.

Keywords: fourth generation, expressions, terms, definitions, network configurations

Smart energy infrastructure and storage options

Christine Damgaard Asmussen is a student of Mechanical engineering from Aarhus university. Having specialized in renewable energy, she is currently finishing her master thesis on the optimization possibilities of grid-connected rooftop solar PV installations.

Optimizing a grid-connected household photovoltaic installation in Denmark

Christine Damgaard Asmussen, Bo Tranberg, Marta Victoria, Aarhus University; Department of Engineering

Christine Damgaard Asmussen (presenter)

The research performed has used consumption data from a household in Aarhus to optimize various parameters of a rooftop photovoltaic (PV) installation. The methods developed can determine tilt and orientation angles that maximize annual energy production, CO2 compensation, self-consumption and net present value (NPV), based on the individual consumers consumption data, as well as determine the optimum PV panel and inverter capacity. The addition of a battery has also been investigated, along with the effect of equipping the battery with intelligence, that determines when to charge and discharge based on the hourly spot prices. Results have shown that the tilt and orientation optima are very flat regardless of which parameter is being maximized, allowing for a great deal of flexibility when determining the tilt and orientation of a PV installation. Furthermore, it is shown that downscaling the inverter and allowing for some curtailment is economically beneficial. The system without battery covers roughly one third of the local demand. Adding a battery is cost-effective when a future cost of 200 €/kWh is assumed. In that case, self-consumption increases from 30.5% up to 54.2%. Applying perfect foresight to the battery only improves the NPV by 6% compared to a myopic dispatch strategy. Continued research will determine the effect of different self-consumption frameworks on the NPV and investigate what political actions can be made to incentivize private PV installations.

Keywords: Optimization, Rooftop solar PV, Energy storage, Self-consumption, Grid connection

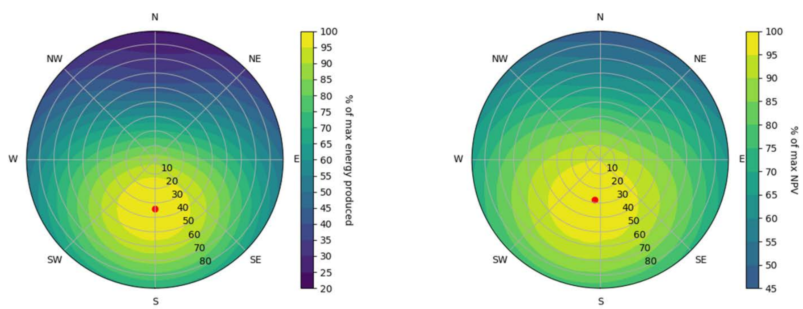

Figure 1 The tilt and orientation optimizations that maximize energy production and NPV

Diederik Coppitters is a PhD candidate in robust design optimization of hybrid renewable energy systems at the University of Mons and Free University of Brussels. In his work, he aims for computational efficiency, an elegant decision making process and a complete uncertainty characterization.

Epistemic and aleatory uncertainty quantification of a grid-connected photovoltaic system with battery storage and hydrogen storage

Diederik Coppitters, University of Mons; Ward De Paepe, University of Mons; Francesco Contino, Université Catholique de Louvain.

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Batteries and hydrogen storage enable intermittent renewable energy to comply with energy demand continuously. During the techno-economic evaluation of such systems under uncertainty, the applications are limited to linear models and a handful of generic uncertain parameters (<5) (e.g. Normal distribution with generic variation). This characterization results in suboptimal operation, highly-sensitive to real-life uncertainty. To determine the uncertainty in a grid-connected photovoltaic system, supported by batteries and hydrogen storage, we first characterized the uncertainties through probability-boxes, leading to a clear distinction between the uncertainties related to lack of knowledge (epistemic), and uncertainties related to natural variation (aleatory). Thereafter, we propagated the probability boxes with a novel sparse Polynomial Chaos Expansion method to determine the sensitivity indices. The results illustrate that designs supported by storage systems achieve a smaller levelized cost of exergy variance, as the dependency on highly-uncertain grid and gas prices is reduced. Moreover, the main drivers of the epistemic and aleatory uncertainty on the objective are highlighted, resulting in specific guidelines on which parameters require additional knowledge and which parameter uncertainty should be reduced by external measures. The guidelines will decrease the variance in an efficient and cost-effective way, leading into an improved robustness of the system operation.

Keywords: Energy storage, Global sensitivity analysis, Levelized cost of exergy, Uncertainty quantification.

Steven Dijkstra-Downie is based in Edinburgh, UK. He is a mechanical building services and renewable energy Engineer. His expertise is in low-energy building services design, district heating and cooling networks. He promotes the use of Scandinavian design principles, such as 4th and 5th generation district heating.

Energy Strategy for Expanding Scottish Towns Greenspaces, waterbodies, shared ambient loops, heat pumps and PV to heat and power town growth projects

Steven Dijkstra-Downie, Sweco UK

Steven Dijkstra-Downie (presenter) steven.dijkstra-downie@sweco.co.uk

Technical proposals are being developed by Sweco UK for a model Scottish town, to create low or zero-carbon heating and power supplies, smart heat and power systems and demand response combined with energy storage. The problems faced and concepts proposed are readily applicable to towns across the UK and abroad that have significant housing growth over the next decade. Energy solutions are being considered to suit various building types and service, such as heat, building power and EV charging. Solutions must be feasible, environmentally friendly and preferably replicable, and be appropriate for connecting to existing properties when they are refurbished. Banning natural gas for new-build projects and constrained grid connections mean innovative solutions are sought, providing opportunities to implement concepts previously considered unfeasible for such projects. Large-scale, shared borehole arrays and closed-loop, water-source collectors in large waterbodies would connect to individual heat pumps. As the domestic and non-domestic plots are built-out, smaller clusters of borehole arrays can be linked together. Multi-megawatt, ground-mounted solar PV arrays could power the heat pumps, the buildings, and provide power for EV charging, with back-up from battery storage and power grid. Project seeks to avoid fossil fuel use and retain grid connection at present-day capacity, despite significant growth and electrification of heat and transport.

Keywords: Climate emergency, air pollution, smart grid, zero carbon, electrification of heat, ground source heat pumps, water source heat pumps, green spaces, shared array, ambient loop, EV, solar PV, hydrogen

Julian Formhals studied industrial engineering and energy science and engineering at the TU Darmstadt, where he is now a scientific researcher. His work focuses on the modelling, simulation and analysis of geothermal energy systems.

Dynamic transition to a renewable and efficient campus solar district heating grid with integrated medium deep borehole thermal energy storage

Julian Formhals, Technical University of Darmstadt, Geothermal Science and Technology; Hoofar Hemmatabady, Technical University of Darmstadt, Geothermal Science and Technology;
Frederik Feike, Technical University of Darmstadt, Institute for Technical Thermodynamics;
Bastian Welsch, Technical University of Darmstadt, Geothermal Science and Technology;
Ingo Sass, Technical University of Darmstadt, Geothermal Science and Technology

Julian Formhals (presenter) formhals@geo.tu-darmstadt.de

The campus district heating grid plays a key role in reaching the ambitious energy saving and emission goals of the TU Darmstadt for 2050. A combination of efficiency measures, integration of renewable energies, waste heat utilization and seasonal thermal energy storage is being considered to achieve these targets. Recent studies have shown large energetic and environmental benefits in a lowering of the district heating grid's temperature level and in the thermal management of existing heat sinks and sources. The construction of a cooling grid, high temperature cooling of a supercomputer and the installation of a sophisticated monitoring system are measures, which already have been or are currently being implemented. A planned pilot medium-deep borehole thermal energy storage could be used to store (solar) thermal energy on a seasonal time scale. However, the transition to a 4th generation district heating grid will be a step-wise process. Renovation of the existing building stock and the DHC infrastructure will most likely take the next decades to be completed. A numerical case study is presented in which this step-wise transition is considered. For this purpose, the campus district heating system is modelled in Modelica, using new developed solar district heating and borehole thermal energy storage models. Finally, a Life Cycle Assessment approach is used to compare different transition scenarios.

Keywords: solar district heating, borehole thermal energy storage, seasonal thermal underground storage, Modelica, life cycle assessment

Luka Herc, bacc. eng. mech., is a graduate mechanical engineering student at the University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture. He works on the modelling of energy systems based on high integration of renewable energy, at SDEWES Centre (Croatia) and collaborates on Horizon2020 project LOCOMOTION. His scientific interest is focused on energy planning, which he pursued by solving similar tasks at Faculty of Mechanical Engineering and Naval Architecture and Energy Institute “Hrvoje Požar”. His work has been focused on tackling challenges of renewable energy integration in energy systems in transition.

Economic viability of flexibility options for smart energy systems with high share of renewable energy

Luka Herc, University of Zagreb Faculty of Mechanical Engineering and Naval Architecture; Antun Pfeifer, University of Zagreb Faculty of Mechanical Engineering and Naval Architecture; Fei Wang, North China Electric Power University Department of Electrical Engineering; Neven Duić, University of Zagreb Faculty of Mechanical Engineering and Naval Architecture;

Luka Herc (presenter) antun.pfeifer@fsb.hr

The European Union has with the passing of European Green Deal set a plan to switch to carbon neutral economy. Main direction of decarbonization of energy systems lies in the implementation of renewable energy systems, but integration problems arise at higher shares of renewable energy, due to their variability. To tackle this problem, various demand response technologies and flexibility options can be used. This includes coupling of sectors with implementation of technologies as vehicle to grid, power to heat, increasing the flexibility of thermal power plants, introducing flexibility of demand and pumped hydro storage. The goal of this research is to show the most economically viable dynamics of achieving the high renewable energy share in combination with different flexibility options on a case study. Application of flexibility options is considered with the goal of keeping critical excess electricity generation within 5 % of total electricity demand. The simulations are performed with the combination of energy planning software EnergyPLAN and a Python code in order to automate solving a large number of simulation cases. Results show that the most effective technologies for critical excess electricity reduction are power plant flexibilization and vehicle to grid. It should be also noted that their effectiveness is related to already achieved flexibility and renewable energy penetration in a way that technologies with lower capital expenditures should be applied first.

Keywords: Energy system modelling, EnergyPLAN, Renewable energy integration, Demand response, Decarbonization

Martin H. Kristensen is an industrial postdoc employed at AffaldVarme Aarhus, the second-largest district heating company in Denmark, in collaboration with Aarhus University. He specializes in the cross field between building energy modelling and smart meter data applications.

Heat load demand response experiment in social housing apartments using wireless radiator setpoint control

Martin Heine Kristensen, AffaldVarme Aarhus; Henrik N. Knudsen, Department of the Built Environment, Aalborg University; Toke Haunstrup Christensen, Department of the Built Environment, Aalborg University; Lisbet Stryhn Rasmussen, AURA Energi

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In recent years, a significant number of studies have indicated a potential of utilizing the thermal mass in buildings to generate flexible heating demand through demand response (DR) schemes. Being able to provide flexibility to a district heating system this way may be used to absorb parts of the daily consumption peaks that often occur during morning hours. Different DR schemes and implementations have been proposed in the literature, but only a few studies have documented any practical effects.

In this abstract, we present the results of a field study concerning scheduled DR events on the radiator heating system in 10 social housing apartments during morning peak load hours. Based on initial focus group interviews of the tenants, three different DR schemes were tested using wirelessly controlled radiator thermostats over the course of two months: 1) radiators turned off for 1h [07.00-08.00]; 2) radiators turned off for 3 hours [06.00-09.00] with +1°C preheating for 2h [04.00-06.00]; and 3) radiators turned off for 3 hours [06.00-09.00]. In addition, a baseline was determined by periods of no DR actions. The heat load was measured using meters in each apartment and air temperature was measured separately in each room. Any potential thermal comfort issues were evaluated using weekly online questionnaires and a hand-written logbook filled out by the tenants. Finally, the tenant's experiences with the DR schemes was evaluated by interviews of the tenants.

Keywords: district heating, demand response, flexible demand, radiator, setpoint control, thermal comfort, questionnaires

Poul Kristensen has worked internationally with research and demonstration projects in the area energy efficiency and renewable energy in buildings for more than 40 years.

Wind + sun for 100% RE heating of buildings

Poul E. Kristensen, director, Compact Heat Storage ApS

Poul E. Kristensen (presenter) poul.erik.kristensen@gmail.com

Heating of Danish dwellings needs to be converted from fossil fuels to 100% renewable energy. Over the next 10 years, there will be a massive conversion from fossil fuels to electric heat pumps for heating. These heat pumps must be flexible so that they run only when renewable electricity is abundantly available, and they must have a heat storage system connected to secure uninterrupted heat supply.
Periods of "wind drought" often have sunshine available, but the production from central solar PV systems cannot make up for the shortfall of wind energy. However, if a decentral solar thermal heating system is connected to the storage system, then solar energy can make up for the lack of wind electricity in periods with wind drought.
Compact Heat Storage ApS have developed an innovative storage system to be used at single family houses. During windy periods, the storage tank will store heat from the heat pump, whereas during sunny days, solar energy will be stored. Using actual data from Energinet.dk, the performance of such a heat pump and solar heating system have been analyzed. The result is that this heat pump/solar energy system can reach a RE autonomy of close to 100%. The presentation will cover the analysis of how RE autonomy can be reached, the design of the innovative storage system and a presentation of the user economy for the client.

Keywords: Wind energy from the grid, on site solar energy, compact storage system, 100% RE year round

Kertu Lepiksaar started her PhD studies in 2020 after graduating Master's studies in Tallinn University of Technology. Her interests in research are modelling energy systems and thermal engineering.

Increasing CHP flexibility to improve energy system efficiency

Kertu Lepiksaar, Tallinn University of Technology; Vladislav Mašatin, AS Utilitas; Eduard Latõšov, Tallinn University of Technology; Anna Volkova, Tallinn University of Technology

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Smart energy grids include smart thermal and electricity grids. The connecting link between them is the combined heat and power (CHP) plant, which provides both heat and power to the grid. CHPs operate best at full load, but they are also efficient at covering the base load of heat and power demand. The distribution of heat and electric loads leads to a decrease in the working time of the CHP and reduced energy efficiency. CHPs are designed for stable heat and electric loads, so their ability to cope with peaks and lows needs improvement. This paper explores various solutions aimed at increasing CHP flexibility. The flexibility of an energy system helps in transforming the existing energy system into a smart energy system and makes integrating various renewable energy sources (RES) into existing networks easier. CHP flexibility extends CHP working time and improves energy efficiency of the system. The examined solutions include coupling CHP with district cooling, electric boilers, and long-term thermal energy storage (TES) or short-term TES, which will help balance heat and power loads and allow to introduce RES to the system. In this study, various technical solutions are compared in terms of the following parameters: the increase in electricity generation, primary energy savings, CO2 emissions reduction, energy efficiency, and the necessary investments. In this paper, Tallinn energy system is used as a case study.

Keywords: CHP, energy efficiency, flexibility, TES, district cooling, smart energy system

Rasmus Lund is employed in PlanEnergi - a foundation that conducts consultancy and research activities within energy planning. Rasmus works with district heating related project, both concrete planning and research projects. Rasmus has a PhD in energy system analysis from Aalborg University in 2017.

Combined heat and power storage: Feasibility in a national renewable energy system context

Rasmus Lund, PlanEnergi; Magdalena Kowalska, PlanEnergi

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Renewable energy as wind and solar cannot be controlled and in long periods, this does not coincide with the energy demand. This mismatch between the energy demand and supply is a fundamental problem that can be handled in different ways. Historically it has been tackled on the production side by dispatchable capacity and curtailment of any excess. This approach, however, is challenged by environmental and economic consideration in the renewable energy transition. Hence, alternative flexibility measures are suggested to balance the systems, such as electric batteries even though these have multiple disadvantages, including capital costs, round trip efficiency and environmental impact during its lifecycle. The present study focusses on an alternative to traditional batteries, i.e. compressed heat energy storage (CHEST). This consists of an electric driven heat pump, a thermal storage and a turbine. The heat pump is used to charge the storage and it can be discharged to produce heat and electricity. The advanced energy system analysis tool EnergyPLAN will be used to perform the techno-economic assessment of different conditions and scenarios of its implementation. The existing national scale energy system models for 2050 with large scale integration of renewable energy will be used as a reference case. It is expected to conclude on the effectiveness and efficiency of implementing the CHEST storage in different configurations and identify the market potential for the technology.

Keywords: Energy storage, Renewable energy, Energy system analysis, Carnot battery, Flexible sector coupling

Johannes Röder is a PhD candidate and research associate. He is focusing on renewable and system-beneficial district heating systems. Johannes Röder holds a MSc in mechanical engineering and has experience in geothermal district heating systems, optimization models and energy efficient buildings.

Decentral Heat Storages in System-Beneficial District Heating Systems – an Integrated Optimization Approach

Johannes Röder, Department Resilient Energy Systems – University of Bremen; Uwe Krien, Department Resilient Energy Systems – University of Bremen; Benedikt Meyer, Department Resilient Energy Systems – University of Bremen; Torben Stührmann, Department Resilient Energy Systems – University of Bremen; Edwin Zondervan, Laboratory of Process Systems Engineering – University of Bremen;

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District heating systems have a great potential to support the energy transition towards a renewable energy system. The integration of volatile wind and solar energy sources through sector-coupling demands for flexible and system-beneficial district heating systems. Hence, heat storages will play a crucial role in future district heating systems. In addition to a central heat storage at the heat generation site, decentral heat storages at the customers could provide additional flexibility for the district heating system. At the same time, this concept enables a leaner piping system due to peak-shaving and offers an option of reducing grid losses especially in summer by intelligent load scheduling. This concept is particularly promising in areas with low and medium heat density. This research work evaluates the potential of decentral heat storages for a built-up district within the project QUARREE100. A linear mixed-integer programming model of the district heating system is developed to determine the optimal sizing of the piping network for the case with and without decentral heat storages. The results show that the cost savings due to a leaner piping system do not offset the additional costs of the decentral storages. For an overall assessment, the heat loss savings by intelligent load scheduling are estimated, and the benefits for the flexibility of the entire system are analyzed by a unit commitment optimization model of the heat and electricity sector of the district.

Keywords: district heating system, infrastructure optimization, planning approach, heat storage, optimization model

(a) (b)

Figure 1. Results of the district heating network optimization with two energy supply plants. DN: nominal diameter. (a) Sizing of the piping system without decentral storages. (b) Sizing of the piping system with decentral heat storage of 1 m^3 at each customer. The decentral heat storages permit a smaller diameter at the distribution lines due to peak-shaving. Background map: OpenStreetMap contributors.

Converting wastes efficiently and flexibly for grid-balancing services and sector coupling

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With the unique feature of the solid-oxide cell stack, i.e., the same stack can work either in fuel cell mode for power generation or electrolyzer mode for power storage, waste-to-electricity and waste-to-fuel can be merged into one single plant: Wastes are gasified first into syngas, which is used in the stack for power generation when electricity is needed by the electrical grid or converted to methane when excess renewable power is available from the grid as shown below. Such dual-mode plants have the advantage of gaining additional profit of grid-balancing services, enhanced annual operating hours (nonstop over the year), reduced CAPEX, and enhance power storage capability and capacity. The EU project Waste2GridS aims to evaluate the economic feasibility of such plants in 2030 by answering three critical questions, the technical potential, business cases, and bottlenecks. The grid-balancing needs and local waste availability in Denmark and South Italy are predicted for 2030 based on current data and roughly matched with different plant designs. The results show that there are big balancing needs in DK1 and Bornholm island. For large-scale zones, the balancing needs go up to several to several tens of TWh (2-8 GWe), while for Bornholm island, it is tens to hundreds of GWh (below 100 MW). Local wastes (agri and municipal wastes) are enough to drive such plants to contribute significantly to balancing the electrical grid and sector coupling by methane production.

Keywords: grid-balancing, waste-to-energy, reversible solid-oxide stack, waste gasification, power-to-x

Hamza Abid has a background in electrical engineering and his interests are within energy modelling and data analysis for enabling the energy transition. With a fascination for sustainable energy technologies, he joined a double master's program by EIT InnoEnergy in Energy for Smart Cities. After completing his first masters at KU Leuven in Belgium he has then moved to Sweden for his second masters at KTH Royal Institute of Technology. For his master's thesis, Hamza Abid worked with a Stockholm based consultancy for techno-economic analysis of energy storage integration with solar PV in West Africa. At present Hamza Abid is working as a research assistant within the SEP group at Copenhagen, mainly engaged with energy efficiency scenario analysis of the European transport sector

Energy storage integration with solar PV for increased electricity access: A case study of Burkina Faso

Hamza Abid, Aalborg University

Electricity access remains a challenge for majority of the West African countries, wherein 5 out of 16 have an electrification rate of less than 25%, with Burkina Faso having only 9% of the rural population with electricity access in 2017. This study presents a techno-economic feasibility analysis of solar PV system integration with conceptualized Pumped hydro storage (PHS) and electric batteries for Burkina Faso. The study explores two cases (a) an off-grid PV with storage system for rural areas and (b) a grid connected PV system for an urban location. The least cost configuration of PV with feasible storage is investigated using HOMER. In the urban case, addition of PV to the grid could drive down the cost of energy by 50% as compared to the present grid electricity prices. Similarly, PV with PHS remains the optimal system configuration for rural case provided the geographic availability of lower and upper reservoirs that leads to a reduction of project cost by more than half. The capital cost of PV remains to be the most dominating factor for both the cases, signifying the importance of introducing policy interventions that reduce the costs of PV for increased electrification in West African countries.

Frederik Palshøj Bigum has a M.Sc. in Engineering from February 2020. He is working with energy planning, especially district heating and cooling from the industrial perspective.

Real-scale integrated renewable energy systems

Frederik Palshøj Bigum, Ramboll Denmark; Fabian Bühler, Ramboll Denmark; Dr. Joaquim Romaní, IREC; Pernille M. Overbye, Ramboll Denmark.

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The heating and cooling of buildings and industry accounted for 50% of the EU energy consumption in 2018. A large part of this energy (70%) originated from fossil fuels. Thus, representing a great potential for integrated renewable energy systems to reach climate neutrality. As part of the H2020 project WEDISTRICT, integrated innovative renewable heating and cooling concepts and technologies for new and existing district heating and cooling systems will be demonstrated. The technologies developed in the project are amongst others solar thermal, biomass and thermal storage technologies.

The concepts will be implemented in four real-scale projects in Spain, Romania, Poland and Sweden. The demonstration cases will present the best practices that can be replicated across different climate zones and building types, transforming the heating and cooling sector.

The aim of the project is to increase the technology readiness level (TRL) and demonstrate its integration in a complete energy system by measuring various KPI's. And to investigate the transferability to different climate zones.

Preliminary results show that the demonstration concepts are overall feasible and allow the operation of DHC with renewable energy all year round. Their transferability to other climatic zones is however limited by the locally available energy sources, which were assessed for Europe.

Funding from the European Union's H2020 research and innovation programme under grant agreement N°857801.

Keywords: District heating, district cooling, integrated energy system, renewable energy, market analysis, concept demonstration.

Matthias Greiml's field of research is modelling and simulation of multi energy systems with high degree of renewable energies as well as storage and sector coupling technologies.

Assessing usage of power-to-gas as an alternative to electricity grid expansion to increase photovoltaic generation in south-east Austria

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Based on installation inquiries for large scale photovoltaic (PV) in some parts of Austria, a strong increase in PV generation is expected in years to come. However, the south-east part of Austria is sparsely populated without major electricity consumers. The existing electricity grid is currently capable of absorbing roughly one third of PV inquiries for installation, leaving significant renewable potentials to be untapped. The aim of this work is to investigate to which extent PV inquiries can be realised without causing congestions in existing electricity grid. To achieve this target two different options are investigated. First solution to be examined is usage of electrolyser at certain locations, feeding hydrogen into natural gas transmission pipelines, tangent the examined area. The second approach considers biogas facilities within examined area, as potential CO2 sources in combination with electrolyser for methanation. Synthesized methan can be feed into local natural gas distribution grid. To examine both solution approaches temporal and spatial resolved consumption and generation data were used in a self-developed multi energy system simulation tool. Simulations show, that PV potentials can be increased significantly by the usage of electrolysers. Depending on electrolyser sizing, up to 80 percent of inquired PV can be realised without strengthening currently existing electricity grid.

Keywords: Sector coupling, renewable energy integration, power-to-gas, multi energy system

Bastian Hase is a part of the research group for renewable energies at the institute for statics. This group has a long history of research on hydropower. Within the workgroup, Bastian Hase is specialized on operation strategies and the production of balancing energy for run-of-river hydroelectric plants.

Using Short-Time Storage Potentials of Run-of-River Hydroelectric Plants for Frequency Control

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The phase out of fossil energy calls for additional renewable balancing energy technologies. We developed an operation strategy that enables run-of-river hydroelectric (ROR) plants to deliver both predictable and constant load and balancing energy. This becomes possible, because the upstream reservoir levels of most plants can, to a certain extent, be flexible, without making further impacts. Simulations were conducted for a projected plant in Bannetze, Germany with a peak-to-peak amplitude of 27 cm. The resulting energy-storage potential is large enough to deliver highly reliable base power held constant for 3 hour intervals with a lead time of 1 hour as well as a significant amount of balancing energy. When upscaling the balancing energy potentials to the whole German ROR hydropower, the national demand of frequency containment reserve (FCR) as well as negative automatic and manual frequency restoration reserve (aFRR and mFFR) can be fully covered, with 95% reliability for FCR and over 98.3% reliability for FRR. For positive aFRR and mFRR the potentials are noticeably lower. At a reliability of 95%, at least 57% of the demand for aFRR could be covered and 51% for mFRR, respectively. On the economic side, even though the total annual energy production is lower the additional delivery of positive and negative aFFR is able to increase the plant revenues, depending on the amounts of control energy produced.

Keywords: run-of-river hydropower, balancing energy, frequency control, short-time storage

Gauthier Limpens is a researcher at UCLouvain. In collaboration with EPFL and Imperial, he is developing EnergyScope, an open source model that optimizes the design and hourly operation of a multi-energy system that accounts for electricity, heat and mobility. The model is used for studies and education.

Intermittent renewable energy integration: assessing the benefits of the flexibility options

Gauthier Limpens, UCLouvain; Xavier Rixhon, UCLouvain; Francesco Contino, UCLouvain; Hervé Jeanmart; UCLouvain

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The energy transition is associated with the massive deployment of renewable energy, mainly solar and wind in Europe. Despite their advantages, these energies are intermittent and drive major changes in the energy system. To counterbalance the intermittency, there is a need for an increased flexibility of the whole system. To reach it, the most relevant approaches can be split into five main categories: (i) imports – exports of both electricity and fuels; (ii) flexibility of the production (fuel based units as a backup); (iii) more flexible demand through sector coupling; (iv) storage; and (v) synthetic fuels. To assess the benefits of the different approaches, we applied the Open Source EnergyScope TD model to two different national energy systems: Belgium and Switzerland. Several low-carbon scenarios in 2035 are optimised to highlight the contribution of the different approaches in terms of cost and emissions savings. The advantage of electrification and storage technologies appears to be the required ingredient to achieve the most affordable energy transition. While sector coupling facilitates the integration of more efficient technologies, storage allows the affordable integration of intermittent renewables and synthetic fuels appear as the last step to reach low-carbon societies.

Keywords: Energy transition, Energy system modeling, Energy storage, Synthetic fuels, EnergyScope

Pia Manz studied Renewable Energy Technology and Systems Engineering. Since 2017 she is a PhD candidate and researcher at the Competence Center Energy Technology and Energy Systems at Fraunhofer ISI in the Business Unit Demand Analyses and Projections.

Future synergies of industrial excess heat potentials and buildings energy demand in Germany

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The EU target to cut GHG emissions by 80 up to 95 percent in 2050 compared to 1990 impli-cates the transformation of the energy system to renewable sources and energy efficiency improvement in all sectors. Space heating demand contributes to about 25%, industrial pro-cess heat demand to about 16% of the final energy consumption. Thus, using industrial ex-cess heat as supply for district heating contributes to improving the efficiency and decarboniz-ing the heating sector and should play a major role in local strategic heat planning. However, estimating future regional excess heat potentials and identifying potential regions for district heating requires disaggregated information on locations of energy intensive plants and heat demand density. We present a scenario-based approach using the georeferenced production capacity of ener-gy intensive processes for estimation of excess heat potentials on different temperature lev-els. This enables the estimation of energy demand and excess heat potentials for over 30 individual production processes taking into account the switch to secondary processes, car-bon-neutral energy carriers or new process technologies. In comparison with other studies, this allows the analysis for district heating system until 2050 while exploiting efficiency poten-tials in all demand sectors.

Keywords: Energy efficiency, system modelling, excess heat, spatial analysis, heat decarbonisation, industrial processes, district heating

Torben Ommen is a Researcher within applied thermodynamics His work focuses on the integration of heat pumps, refrigeration and/or power cycles in the energy system. Examples are numerical and experimental analysis of systems and components, and real-time optimization of thermal processes.

Economic feasibility of fuel-shift appliances supplied by gas, electricity and district heating in Denmark

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In a future energy infrastructure, different utilities like gas, electricity, district heating (DH), district cooling, and charging and fueling of vehicles may be highly integrated. Fuel-shift technologies may potentially provide added value by shifting from a reference utility to an alternative supply scheme in times with low cost, low environmental impact or little strain on a specific supply scheme. A preliminary assessment of the feasibility of fuel-shifting between individual sources was conducted to evaluate the relevance of further development between specific sectors in a multi-carrier energy system. Two basic technologies were identified as candidates for fuel-shift integration, namely direct conversion (1:1) or heat pumping applications (e.g. 1:3 depending on the supply scheme). The additional investments required to allow operational fuel-shift appliances were addressed as three different additional fixed cost (AFC) of between 1000 2017-DKK to 10000 2017-DKK. The analysis revealed that for some fuel-shift pairs the benefit of fuel-shift was significantly higher for private-economic analysis, compared to the socio-economic analysis. This is the case for fuel-shift from electricity to DH or natural gas, where private benefits exceed social-economic benefits. For other fuel-shift pairs, the benefit revealed the opposite trend. A range of solutions which shift from electricity to DH or natural gas allow AFC of between 5000 2017-DKK to 10000 2017-DKK.

Keywords: Fuel-shift; integrated energy system; sector coupling; appliances

Dietrich Schmidt works as head of Department Heat and Power Systems within the research and development division on Energy Economy and Grid Operation. He is responsible for various research projects within the field of energy utilization in buildings, energy supply structures of buildings and communities.

Digitalisation of District Heating Systems

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District heating and cooling (DHC) networks are traditionally operated with a limited number of controls to secure the required supply task and to optimize economics and ecologic performance. An optimised heat generation and overall network operation is possible with more information on the demand and flexibility options. A wider implementation of information and communication technologies opens up for better network management based on real time measurement data. The main objective is to promote the opportunities of the integration of digital processes into DHC systems and to clarify the role of digitalisation for different parts within district heating and cooling systems. Digital technologies are believed to make the whole energy system smarter, more efficient, and reliable and to boost the efficiency and the integration of more renewables into the system. In the future, digital applications might enable district energy systems to fully optimise their plant and network operation while empowering the end consumer. On the other hand new challenges need to be tackled, such as data security and privacy as well as questions about data ownership. The paper presents and discusses the first results from the starting research work within the IEA DHC Annex TS4 on Digitalisation of District Heating Systems – Optimised Operation and Maintenance of District Heating and Cooling Systems via Digital Process Management.

Keywords: digitalization of district heating; operation and maintenance

Vittorio Verda is full professor at Department of Energy of Politecnico di Torino. His research covers a number of different fields including thermodynamics, heat transfer, thermoeconomic analysis and diagnosis of energy conversion systems, fuel cells, and computational fluid dynamics.

Challenges in adoption of district cooling in densely populated areas

Martina Capone, Politecnico di Torino; Elisa Guelpa, Politecnico di Torino; Giulia Mancò, Politecnico di Torino; Vittorio Verda, Politecnico di Torino;

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In the context of district cooling development, there are both opportunities to be seized and challenges to be considered. Integration of renewable sources, waste heat from industries and high efficiency plants represent a very interesting chance, especially if compared with the inefficient cooling units often adopted in warm/hot areas. In this context, some issues make design and operations of district cooling system not straightforward, especially in case of mild/hot climate and densely populated areas (typical of Mediterranean areas). One of the main issues consists in large mass flow rates to be delivered to customers (much larger than district heating), because of the low temperature difference between supply and return line (5°C in case of district cooling vs 20-50°C in case of district heating). This makes both district cooling network design and operations difficult because of large pipelines diameters and large pumping power required. This problem has been tackled from the authors in order to evaluate how the optimal design and operating parameters of a heat-pump-driven district cooling can increase the feasibility of such kind of system in densely populated areas. In particular, the district cooling for a large area is considered, using the same topology of the existing district heating network. The optimal location of heat pumps and booster pumps is investigated in order to make the design an optimal tradeoff between system complexity and size of the pipeline.

Keywords: District cooling, heat pumps, optimization, smart energy systems, power2cool

Marta Victoria (B.Sc. and M.Sc. in Aeronautical Engineering, PhD on solar photovoltaics) She is Assistant Professor at the Department of Engineering of Aarhus University where she researches on modelling of large-scale energy systems with high renewable penetration.

Early decarbonisation of the European energy system pays off

Marta Victoria, Aarhus University; Kun Zhu, Aarhus University; Tom Brown, Karlsruhe Institute of Technology; Gorm B. Andresen, Aarhus University; Martin Greiner, Aarhus University,

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The cumulative carbon dioxide emissions from the European electricity and heating sector between 2020 and 2050 must remain below 21 Gt to meet the Paris Agreement. This carbon budget can be used in different transition paths. We have found that following a Gentle path in which emissions are strongly reduced in the short term becomes cheaper than following a Sudden path in which low initial reduction targets quickly deplete the carbon budget and require a sharp reduction later. Our results support the need for short-term climate action in Europe.

Solar and wind cost have plummeted during the last decade. As a result, a sector-coupled European energy system based on variable renewable technologies can supply electricity, heating, and transport demands at a cost similar than today. Duplicating the highest historical installation rates for wind and solar will be needed to achieve timely decarbonisation, making the transition challenging yet feasible.

A preprint of the work that will be presented can be found here:
https://arxiv.org/abs/2004.11009

Keywords: myopic optimisation, carbon dioxide reduction, grid integration of renewable power,
sector coupling, open energy modelling

Debmalya Biswas is a Principal AI Architect at Philip Morris, Switzerland. He has over 15 years experience working on a variety of topics, e.g., AI, NLP, Privacy, Security. He has worked for leading tech companies including Nokia, SAP, Oracle, and has authored more than 40 technology patents.

Reinforcement Learning based HVAC Optimization in Factories

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Debmalya Biswas (presenter)

Heating, Ventilation and Air Conditioning (HVAC) units are responsible for maintaining the temperature and humidity settings in a building. Studies have shown that HVAC accounts for almost 50% energy consumption in a building and 10% of global electricity usage. HVAC optimization thus has the potential to contribute significantly towards our sustainability goals, reducing energy consumption and CO2 emissions. In this work, we explore ways to optimize the HVAC controls in factories. Unfortunately, this is a complex problem as it requires computing an optimal state considering multiple variable factors, e.g. the occupancy, manufacturing schedule, temperature requirements of operating machines, air flow dynamics within the building, external weather conditions, energy savings, etc. We present a Reinforcement Learning (RL) based energy optimization model that has been applied in our factories. We show that RL is a good fit as it is able to learn and adapt to multi-parameterized system dynamics in real-time. It provides around 25% energy savings on top of the previously used Proportional–Integral–Derivative (PID) controllers.

The full paper is available below for review:

https://www.researchgate.net/publication/341567097_Reinforcement_Learning_based_HVAC_Optimization_in_Factories

Keywords: Energy Optimization, HVAC, Sustainability, Reinforcement Learning, Machine Learning

Henrik Brink is the CEO and chief data scientist of Ento Labs, an Aarhus-based startup applying modern machine learning technology to energy data. He has a background in physics and previously co-founded a startup in Silicon Valley, acquired by General Electric where he served as lead ML engineer.

Identifying optimisation potential in electricity consumption profiles from hourly smart meter data at scale

Henrik Brink, Ento Labs; Kasper Bjørn Nielsen, Ento Labs; Bo Tranberg, Ento Labs; Malte Carøe Frederiksen, Ento Labs

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In the transition to a highly renewable and electrified energy system, the consumption profiles of the individual consumer — industrial, commercial, public or residential — becomes important. In this study, we develop algorithms to analyse smart meter data to continuously determine the optimisation potential of individual consumption profiles to support the smart energy system at scale.

The three main paths to optimising the shape of electricity consumption profiles are: (1) increase energy efficiency, (2) align consumption with renewable production, and (3) assist in limiting fluctuations and peaks in the grid (demand response). All of these require a deep understanding of the individual consumption profile, the effects of internal and external factors, and the state of the energy system, influenced by highly stochastic systems like weather and energy markets.

To that end, we have built an automated machine learning pipeline that connects relevant data sources, such as electricity consumption, weather, building and industry data and builds statistical models of consumption profiles for individual metering points. Through pilot projects our system has automatically identified potential savings of 10-20% in baseload consumption (energy efficiency), 10-50% savings in electricity cost and CO_2 emissions by aligning consumption with renewable production, and simulated potential earnings from bidding in demand response programs at the transmission grid level.

Keywords: energy efficiency, demand response, flexible consumption, machine learning

Sverre Foslie works as a Research Scientist at SINTEF Energy Research. He works mainly with energy efficiency in the industry, industrial heat pumps and integrated energy systems. His fields of interest include integration of energy systems, industrial and in the cross-section towards urban areas.

Integrated heating and cooling in the industry through heat pumps and thermal energy storages – case study of an electrified dairy

Sverre Stefanussen Foslie, SINTEF Energy Research; Ole Marius Moen, SINTEF Energy Research; Michael Bantle, SINTEF Energy Research; Kim Andre Lovas, TINE SA; Bjarne Horntvedt, Hybrid Energy AS; Stein Rune Nordtvedt, Hybrid Energy AS

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Nearly 50% of the world's energy demand is in the form of thermal energy. Industry has high demands for thermal energy in the form of heating and cooling and high peak powers, while large amounts of surplus heat are available and unutilized. Refrigeration processes in the food industry typically reject heat to the surroundings and are one potential surplus heat source. Thermal energy storages (TES) can have a significant impact on reducing peak power and lowering the load on the electricity grid.

At a dairy located in Bergen, Norway, a combined heating and cooling system has been installed, replacing the typical gas fired boilers for heating supply. This makes it the first known dairy where all heating and cooling demands can be supplied by heat pumps. The dairy is connected to district heating (DH) and has solar panels for electricity generation. The system utilizes waste heat to provide heating or cooling at four temperature levels to the process. Waste heat from chillers is upgraded through two heat pump systems, providing heat to the process at 40°C, 67°C and 95°C. DH and an electrical boiler is used to supply the energy deficit, if necessary. TES exist at all four temperature levels, enabling buffering for shorter periods.

This study investigates the performance of the dairy. The focus is on energy savings and operational stability related to the heat pumps and the TES. Results are compared to a traditional dairy to evaluate the overall performance of the dairy.

Keywords: Energy savings, electrification, thermal energy storage, heat pumps, integrated energy systems

Daniel Heidenthaler is a research assistant at the Salzburg University of Applied Sciences in Austria. His research focuses on the field of Smart Buildings and Smart Buildings in Smart Cities. One emphasis is on thermally activated building systems.

Thermally activated building systems in wooden structures

Daniel Heidenthaler, Salzburg University of Applied Sciences, Markus Leeb, Salzburg University of Applied Sciences, Thomas Reiter, Salzburg University of Applied Sciences, Marcel Lippert, Salzburg University of Applied Sciences, Hermann Huber, Salzburg University of Applied Sciences, Thomas Schnabel, Salzburg University of Applied Sciences

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A practicable and cost-effective way of storing energy and thus facilitating the use of renewable en-ergy is the utilization of building mass as thermal storage in form of thermally activated building sys-tems (tabs). Within the ongoing change in construction towards more ecological construction methods, the material wood is becoming increasingly important.
This study deals with the functionality of tabs in wooden structures and is supported by the federal state of Salzburg through grants in the project “Aktiviertes Brettsperrholz”. On the basis of parameter studies within steady-state and unsteady simulations, the functionality and utilization of tabs in wooden structures as thermal storage is investigated. Figure 1 displays, that there are various advantages compared to the common realization of tabs in concrete structures. Although the heating and cooling temperature of the system within concrete constructions is very limited due to comfort criteria, the temperature can vary greatly in wooden structures.
A further important factor regarding the use of building masses as thermal storage concerns the dynamic behavior. Unsteady simulations indicate, that wooden structures can store thermal energy over a long period of time and subsequently release it later on. To conclude, tabs in wooden structures represent an innovative and functional possibility for the storage of thermal energy and hereby contribute to a flexibilization of the energy system.

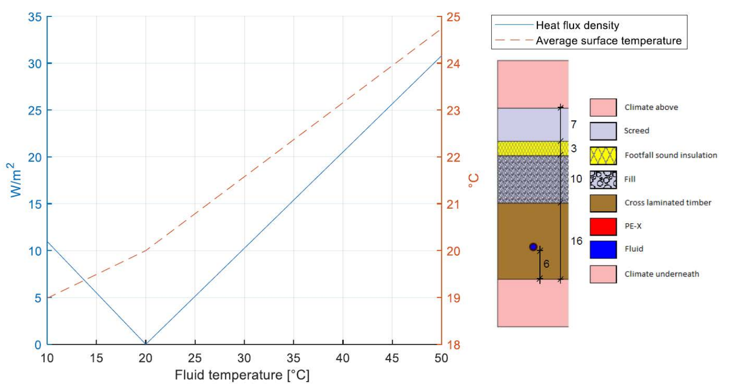

Figure 1: Heat flux density and average surface temperature for a thermally activated building system in wooden structures depending on the fluid temperature, based on the simulation model as depicted. The examined component represents a ceiling, all graphs shown refer to the undersurface. The thermally activated building system can be used both for cooling and heating. The average surface temperature ranges from 19-25 °C, assuming that the fluid temperature is between 10-50 °C. The temperature of the climates above and underneath is 20 °C. All specified dimensions in centimeters.

Marcus Hummel is senior researcher and managing director at e-think. His research focuses on efficient and renewable energy systems, energy economics and policies for space heating and cooling, for district heating as well as for industry.

Using least cost renovation combinations in buildings for developing future heat demand density maps: case studies in three cities in Europe

Marcus Hummel, e-think - energy research; David Schmidinger, e-think - energy research; Andreas Müller, e-think - energy research

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Reducing the heat demand in buildings is a key pillar for reaching 100% renewable energy (RE) systems. In order to build up economically meaningful 100% RE systems it is important to understand the effects of different renovation scenarios on the costs and the heat demand densities. In this work we develop future heat demand density maps for three cities in Europe by identifying least cost renovation combinations for reaching pre-defined saving targets. In a first step we set-up consistent databases of the buildings in the cities based on data from the city administrations. Then we compile 10 different renovation packages for each of the buildings each reaching different relative savings. After that we identify the cheapest combinations of renovation packages in the different buildings for reaching pre-defined saving targets in the cities. For each of the saving targets we derive a heat demand density map. The results show that the changes in the heat demand density maps between the current state and potential future scenarios remarkably differ between the different cities. These depend largely on the composition and the location of the buildings in the area. The developed method helps to identify meaningful levels of heat savings at local level by comparing the costs of savings with the costs of heat supply. The resulting maps can also be used to identify economic district heating areas as well as renovation priority areas.

Keywords: Building renovation, heat savings in buildings, heat demand density maps, GIS, building stock model, Invert/EE-Lab, renovation priority areas, local heat planning, economic district heating, Hotmaps

Paolo Leoni, has been working as Research Engineer at AIT Austrian Institute of Technology GmbH in the fields of District Heating and Cooling and Integrated Energy Systems since 2016. Before, he worked as Project Manager and Engineer for biomass, geothermal, solar thermal power at Enel (Italy).

Lowering the operating temperatures in old-generation district heating systems: first results from the TEMPO demonstration project in Brescia (Italy)

Paolo Leoni, AIT Austrian Institute of Technology GmbH; Aurelien Bres, AIT Austrian Institute of Technology GmbH; Ilaria Marini, A2A Calore & Servizi; Alessandro Capretti, A2A Calore & Servizi

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The district heating (DH) system of Brescia started operating in 1972 and has grown in the years hosting technologies of the 2nd and 3rd generation. Today, it represents the largest DH system in Italy, supplying about 1000 GWh/a heat. Within the H2020 project TEMPO, a peripheral branch of the network was selected to demonstrate a local reduction of the operating temperatures. The site was prepared in 2019 by installing a return-to-supply mixing station with a dedicated control system and by ensuring the acceptance of the temperature reduction with extensive customer engagement campaigns. During the first demonstration phase, performed in the heating season 2019-2020, the local supply temperature was decreased without significant issues to values below 90 °C, while the remaining network continued operating at the usual 115-120 °C. The risk of heat undersupply was prevented by the local controller. The analysis of the available monitoring data showed an important reduction of the primary energy demand and of the CO_2 emissions for the site heat supply. Additional improvements are expected in the heating season 2020-2021 with the implementation of smart technologies and the optimization planned in the second part of the project.

Keywords: District heating, 4GDH, Temperature reduction, Customer engagement

Antoine Levesque is researcher at Potsdam Institute for Climate Impact Re-search and
Technical University Berlin, Germany. His current work focuses on the potential of
buildings' energy demand in climate mitigation scenarios, and its representation in
Integrated Assessment models.

Decarbonising buildings energy services through demand, and supply

Antoine Levesque, Potsdam Institute for Climate Impact Research (PIK); Robert C. Pietzcker, Potsdam Institute for Climate Impact Research (PIK); Gunnar Luderer, Potsdam Institute for Climate Impact Research (PIK)

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Buildings energy consumption is one of the most important contributors to GHG emissions worldwide. In essence, two strategies can lead to a decarbonisation of buildings: reducing energy demand and reducing the carbon content of energy. While the potential of energy demand reductions can be analysed in buildings specific studies, the second strategy is mostly a question of the energy supply. Combining both strategies requires therefore an energy system perspective.
In this study, we use the integrated assessment model REMIND to investigate the decarbonisation of buildings at the global level and in a 1.5°C scenario. The model covers both decarbonisation options on the buildings side, as well as on the energy supply side. It optimises the full energy system to meet the 1.5°C target at the lowest cost.
We find that final energy demand decreases by 26%, both through a decline in useful energy demand and through improvements in conversion efficiency.
Nevertheless, more than 80% of the decrease in CO2 emissions is accounted for by reductions in the carbon content of energy, through supply decarbonisation combined with electrification and fuel switching. These figures show that analysing the decarbonisation of buildings energy services necessitates considering together the reductions in energy demand, the reductions in the energy carbon content, and the interactions between both strategies.

Keywords: Buildings decarbonisation, energy demand, 1.5°C scenario, integrated assessment model, global study

Chiara Piccardo is a researcher of the Sustainable Built Environment Research (SBER) group, led by Professor Leif Gustavsson, at Linnaeus University, Sweden. She has a background in building technology, and her research focuses on energy efficient buildings and life cycle analysis.

Life cycle cost and primary energy analysis of a multi-storey residential building retrofit to different energy levels with varied materials

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The study analyses the life cycle cost efficiency and primary energy use to retrofit a multi-storey residential building to an annual final energy use of 50 and 30 kWh per heated floor area, respectively, corresponding to two Swedish passive house standards. We compare the net present value (NPV) of the net primary energy savings of the retrofitting options and the cost of them. The retrofit includes additional insulation to basement walls, exterior walls, and attic floor, new windows, efficient water taps and ventilation heat recovery. We assume the use of different building materials, including glass wool, rock wool and wood fibre for thermal insulation, and aluminium, brick and wood for cladding. We also analyse the effects of various energy scenarios on the primary energy savings and costs of the building retrofit. The heat supply is from bio-based or electric heat pump district heating. The electricity is from standalone fossil gas (100%) or bio (30%) and wind electricity (70%) plants. The biomass cost is based on current or 60% higher prices. Retrofit to 50 kWh per heated floor area is cost efficient while the 30 kWh level is close to be cost efficient for higher biomass prices. The primary energy use to produce the retrofit options is much smaller in all cases than the operation primary energy savings of them. The cost for different retrofitting material options is rather similar while the production primary energy use is much lower for wood based materials.

Keywords: Building retrofit, life cycle, cost analysis, primary energy use, renewable energy, district heating

Different portfolios of measures to improve efficiency in the residential sector in Greece towards the achievement of the 2030 targets

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The recent National Energy and Climate Plan in Greece foresee very ambitious targets and innovative financing schemes for improving the energy efficiency of residential buildings in the upcoming decade. However, while objectives are a step in the right direction, the planning lacks specifics in terms of implementation details. Our work addresses the later by analyzing the cost-effectiveness of different portfolios of measures, along with their combined potential, in contributing to the achievement of the national targets towards 2030. Modeling exercises will evaluate the performance of different conventional measures, in terms of their long-term energy savings, focusing also on aspects of energy poverty that have not been thoroughly addressed so far in the literature. In addition, considering the potential of smart energy management systems and digital monitoring tools, our work will also include measures that aim at improving demand-side management and optimal control of heating, ventilation, and air conditioning systems. To do so, the Dynamic high-Resolution dEmand-sidE Management (DREEM) model will be used, developed in-house, along with the Tabula Webtool to account for the characteristics and the properties of the different building typologies in Greece. The model is currently under further development to simulate such scenarios in the context of the EC-funded H2020 project “SENTINEL”.

Keywords: Greece, Policy targets, Energy efficiency, Residential sector, Demand-Side Management, Smart Management Systems, HVAC

Alice Dénarié is a research fellow at the Energy department of Politecnico di Milano since 2012 . Her research activity includes energy efficiency in DH&C and its integration with renewable energy sources. She has finshed her PhD on DH modelling in 2019.

Assessment of renewable and waste heat recovery in DH through GIS mapping: the national potential in Italy

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This work aims at showing the unexploited potential of waste and renewable heat recovery in Italy through detailed mapping of these sources. The ambition is to highlight the areas with an important heat recovery potential that, once matched with suitable heat demand, could be exploited through DH expansion. The recoverable heat sources have been analysed also in terms of geographical location, and recovery costs with a special focus on temperature levels and the consequent additional costs for temperature upgrades. The input data come from national databases, which implies obtaining a wider results set with respect to international existing studies on the same subject. Two different approaches have been used to map potential heat: one to quantify existing waste heat recovery from industrial processes, waste to energy plants, waste water treatment plants and datacentres and one to estimate the energy coming from potential new plants based on biomass, geothermal energy and electrolysis plants Results shows that for a total heat demand for the civil sector of 400TWh the national available waste and renewable heat amount to 270TWh. When considering the geographical matching at NUTS3 level with the demand, 95 TWh of waste heat come out to be recoverable in DH. These results show the huge unexpressed potential of waste heat use in Italy and how its mapping is essential to properly estimate the utilization potential. This work has been commissioned by AIRU, Italian DH association.

Keywords: Waste heat recovery, renewables, energy mapping, energy planning, DH potential

Mostafa Fallahnejad is an associate researcher at the EEG at TU Wien. He holds a master's degree in Power Engineering from Technical University of Munich (TUM). He is involved in the field of energy system modelling as well as H&C planning. Mostafa has developed economic models for studying district heating potentials and district heating grids. His research interest is mathematical modelling within the energy sector.

District Heating Grid Planning

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Due to high investment and long payback time, district heating (DH) grid should be planned precisely. DH grid consists of transmission pipes with distribution pipes branching out [1]. This study presents a mathematical optimization model for determination of economic DH areas and planning routes, sizes and costs of a district heating transmission and distribution network. In the formulation of the model, conditions for satisfying redundancy criteria against unavailability of heat sources are defined. The approach will be integrated as a separate module in the DH-Plan model [2]. DH-Plan model maximizes the profit with respect to spatial and economical aspects of implementing district heating system. The model is applied to the case study Brasov, Romania.

Methodology
In order to identify the DH grid, DH plan follows these steps:
Reduce the study area to the potential DH areas based on method introduced by Persson et al. [3] under following conditions:
- Distribution grid cost ceiling (EUR/MWh),
- Available capital for investment in grid (Million EUR).

Breaking potential DH areas into smaller areas using clustering module of DH-Plan,
- Seeds for clustering are obtained from the skeleton of the potential DH areas (step 1).
- For clustering, a minimum and maximum heat demand in each cluster is defined.
- Clustering is performed based on minimization of distance of cluster members to the selected seeds by an optimization model.

In each cluster under assumption of heat supply via one substation (as an interface between transmission grid and distribution grid):
- Obtain economic distribution grid costs, configuration, dimension, heat losses;
- Heat demand that can be economically supplied in the clusters.

Calculate shortest path routes between all pairs of cluster centroids and heat sources based on street routes and constitute a distance matrix.
Check redundancy constraints if there is any and add them to the model parametrization.
Feed the input data and distance matrix to the optimization model.
Get among all, economic clusters, cost optimal transmission and distribution lines' routes, costs and sizes.

RESULTS

Fig. 1 shows the results of the model under a certain scenario for the case of Brasov in Romania with a limited available capital for investment in DH grid. On the top-left corner, the heat demand densities are illustrated in small scale to present the hot spots in the city. Determination of DH grid routes, dimensions and costs are complex tasks. The first step in determining potential DH areas and the use of clustering model reduce the overall complexity of the problem substantially. Furthermore, the approach allows for a step-wised planning of extension of grid. For example, the construction of grids can be started from clusters with higher profit. The possibility to study redundancy constraints guarantees uninterrupted heat supply even if a heat supply unit is unavailable and contributes in the security of supply.

This method provides a generic approach. Therefore, the outputs should be regarded as pre-feasibility results that can facilitate detailed heating planning in study areas.

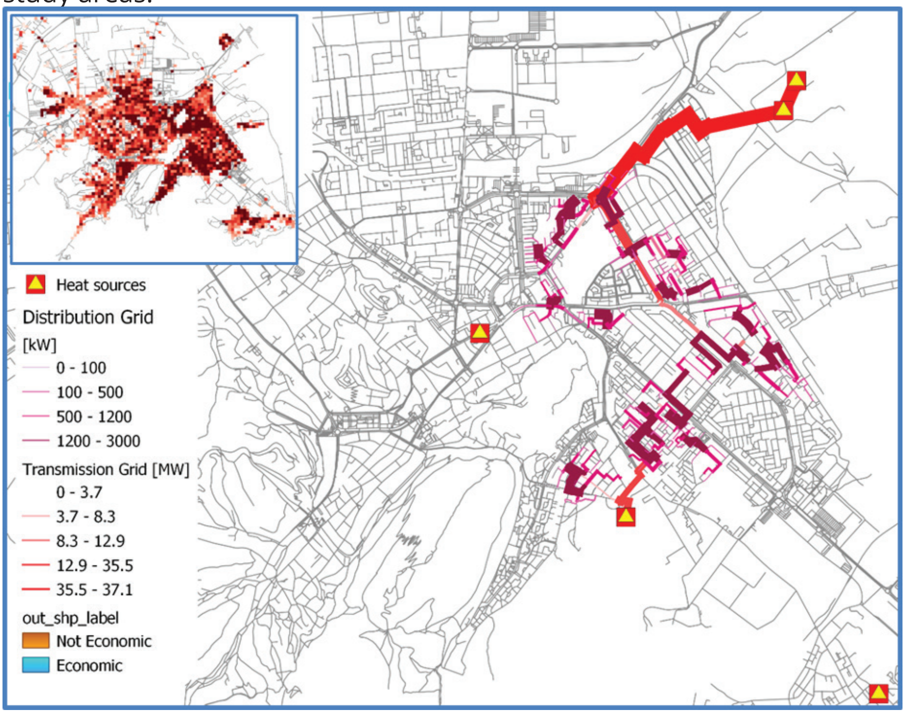

Figure 1: Illustration of transmission and distribution grids as well as utilized heat sources under a certain user-defined scenario.

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Keywords:

Geographical information systems (GIS) for energy systems, heat planning and district heating

Fabrizio Fattori graduated in Environmental Engineering in 2011 at the University of Pavia and received a Ph.D. in the field of Energy System Modeling and Analysis in 2016 from the same Institute. He is currently Post-doc at Politecnico di Milano.

A Regression Model to Estimate the Dwelling-Network Connection Length Starting from Aggregated Information per Census Area

Fabrizio Fattori, Politecnico di Milano; Samuel Macchi, Politecnico di Milano; Alice Dénarié, Politecnico di Milano; Mario Motta, Politecnico di Milano

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Studies aiming at assessing district heating potential usually compare costs of individual heating systems to those of a possible district heating system within a given area. Among the costs, the investment for the dwelling-network connections might be neglected by utilities but must be considered for a comparison from a system point of view. In this work we develop a model to estimate the length of the dwelling-network connections starting from aggregated information provided per census area. The model is based on a power regression built on measures of simulated connections topology and the ratio between number of buildings within a census area and the overall surface of the same census area. The simulated connections are elaborated through a Geographic Information System (GIS) software and based on the georeferenced information available within the Italian census of buildings (2011) and the buildings database of OpenStreetMap. The model can be used within Italy or other geographical contexts with a similar identification of census areas. It can otherwise be replicated and calibrated with the same approach elsewhere since it is based on open data.

Keywords: district heating, network, regression model, OpenStreetMap, open data, GIS, census

Markus Groissböck is a PhD student at the Institute for Construction & Materials Science, University of Innsbruck. His research interests lie in medium- and long-term investment planning within the energy sector considering distributed and volatile energy resources on district and regional level.

Energy hub optimization framework based on open-source (software & data) – Review of frameworks and concept for districts & industrial complexes

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Historically, planning for e.g. energy, water, and natural gas was done for each energy source separately and independent from each other. The massive call for decarbonizing all sectors (incl. e.g. residential, commercial, industry) to keep global warming 'well below 2 °C' requires cooperation of all consumers and producers including parties involved in energy transportation. Therefore, all energy consuming sectors have to be integrated into one single 'integrated resource planning' (IRP) approach. More and more universities and research institutes develop open-source optimization models. Nevertheless, up to now quite limited cooperation has evolved in developing energy optimization frameworks jointly. After an intensive assessment of existing open-source optimization models, open-source data, and open-source libraries (mainly based on Python) this work aims to design an energy hub optimization framework based on open-source software and data. The proposed framework covers data collection (infrastructure, energy demand, renewable energy potentials), optimization framework execution, and result visualization, comparison, discussion and replication. The current status of research shows the comparison of several energy optimization frameworks and shows the potential options for enhancements as well as the current draft of an energy hub optimization framework completely based on open-source and able to cope with district, commercial and industrial details.

Keywords: open source, optimization, energy hub, multi model energy system, district, industry

Nina Kicherer is a research associate at the District Heating research team at the Hamburg University of Applied Sciences. Within the research team, she focuses on strategic heat planning in DHS which was also the topic of her master thesis.

Design of a District Heating Roadmap for Hamburg

Nina Kicherer, Hamburg University of Applied Sciences; Peter Lorenzen, Hamburg University of Applied Sciences, Universitat Politècnica de València; Hans Schäfers, Hamburg University of Applied Sciences

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This paper presents a methodology for the development of a transformation strategy for large-scale district heating systems (DHSs). Using this methodology, a roadmap for Hamburg's municipal DHS is derived with an exemplary scenario for a climate-neutral heat supply in 2050. The city of Hamburg is currently in the process of transforming its municipal DHS towards climate-neutrality until 2050. So far, a blueprint for the development of such a long-term strategy does not exist. The presented scenario is based on an analysis of the future heat demand and of the regional renewable heat potentials. In the resulting generation mix, the expected heat demand in 2050 can mainly be supplied by industrial waste heat, large heat pumps and biomass. To meet the city's climate goals, fossil fuels will have to phase out and even waste incineration needs to be reduced drastically. After the application to the DHS of Hamburg, the methodology and results are transformed into a general approach for municipal heat planning that supports the transfer to other cities. Most importantly, strategic heat planning should be integrated into municipal administration to guarantee a flexible planning process. The paper also reveals shortcomings of current available methodologies and tools for strategic heat planning, such as spatially resolved forecasts of the heat demand and regional potentials for renewable heat sources, which should be tackled in future scientific research projects.

Keywords: District heating transformation, District Heating Roadmap Hamburg, District heating scenario, Strategic heat planning

Hannes Koch is a doctoral student at the University of Applied Sciences “THM”. His work is concerned with the simulation of regional energy supply systems, aiming to determine transformation paths leading to a state that meets future requirements in terms of sustainabilty and profitability.

Rooftop photovoltaic - an algorithmic solution for obtaining total potential power generation by processing solar irradiance data

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This paper proposes a novel method for determining potential power generation by rooftop photovoltaic power stations based on high resolution raster data sets which contain information about global irradiation. For processing these raster data sets, an algorithm is introduced which is suitable for minimizing the computation time needed due to measures of vectorization and reduced overall memory latency. It offers a novelty aspect by additionally evaluating geometrical traits of rooftops. While many rooftop areas may be suitable for hosting photovoltaics modules based on their exposure to solar irradiation, the shape, size and and orientation of their respective subareas might prevent PV modules from being installed. The algorithm written for the task of analyzing large areas' rooftop photovoltaics hosting capabilities uses data sets containing global irradiation on rooftop surfaces to determine whether a rooftop is suitable for hosting photovoltaics modules. It takes into account both the exposure of the surface to global irradiation and its geometrical features to identify panes which are capable of hosting. To efficiently perform the latter, the algorithm uses a method of analyzing every raster cell's neighbors in a vectorized manner, allowing it to run the analysis simultaneoustly on every cell in the data set rather than sequentially.

Keywords: Photovoltaic rooftop potential, GIS-Data, raster data processing, vectorization

Figures: Results of the algorithm, represented in the GIS software QGIS

Samuel Macchi is a Research Fellow and GIS expert at the Energy department of Polytechnic University of Milan. He recieved a master's degree in Environmental and Geomatic Engineering from the Civil and Environmental department of the same institute in 2019.

A validated method to simulate district heating network topologies to enable assessing district heating cost

Samuel Macchi, Politecnico di Milano; Fabrizio Fattori, Politecnico di Milano; Alice Denarie, Politecnico di Milano; Mario Motta, Politecnico di Milano

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The evaluation of the investment costs of a district heating network requires knowledge of its topology. However, when assessing district heating potential the typology is not known a priori and a simulation is required. One method for the generation of simulated networks involves the use of Minimum Spanning Tree (MST), from the graph theory. We studied a method that simulate the network through a MST that links given census sections. The borders of the census sections are used as a starting point for the identification of the MST, after elimination of those not passing through the local road network. We validated the method by running experimental simulations in areas where the district heating networks were already present, allowing the comparison of the respective lengths. The validation showed an overestimate that varies from 10 to 140% but a systematic behaviour of the error can be detected. In particular, the error decreases with the number of buildings and the extension of the census sections. The study of the error and the identification of correlations allow correcting the length of the MST to improve the prediction of investment costs.

Keywords: District heating, network, GIS, validation, minimum spanning tree

Johannes Pelda is a PhD Fellow in the field of energy systems. His focus is especially on district heating systems. He researches methodologies and strategic approaches to integrate renewable energies, also considering the utilisation of low-grade waste heat sources.

FERNWÄRMEATLAS – An Online Tool to Collect Information about District Heating Systems in Germany

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Currently, district heating systems have great potential to minimize CO2 emissions in the heating sector in Germany. However, the integration of renewables and sustainable technologies in existing district heating systems demands lower temperature levels. A thermo-hydraulic simulation of the individual system would be necessary to analyse, overcome and delete bottlenecks. There is currently insufficient access to technical data and topologies of existing networks to conduct these analyses. Information about district heating systems is not centrally available or publically accessible. Consequently, information about district heating systems is widely spread and inconsistent in Germany. How can the necessary information to analyse district heating systems be collected and provided to the community? The FERNWÄRMEATLAS brings an online tool to researchers and other interested parties that shall ease the process of accessing information on district heating systems. It is an interactive database that enables interested parties to bring in their information and thus to be part of a publically available information system. It aims to aid the research on the transition of existing systems to systems of the 4th generation by providing relevant key metrics. The tool itself supports this process through generically produced data based on open data and previously developed algorithms. It provides the base information and lives on the input of its users' research results.

Keywords: Interactive Database, Topology, District Heating Networks, Key Metrics

Morten Karstoft Rasmussen has a background in nanoscience and physics from Aarhus University, and have previously worked in the field of metrology at the Danish Technological Institute. Now he is employed as a Data Scientist in the Analytics Team at Kamstrup, focusing on digitalization within district energy.

Data driven asset management – online distribution grid analysis based on GIS and meter consumption data

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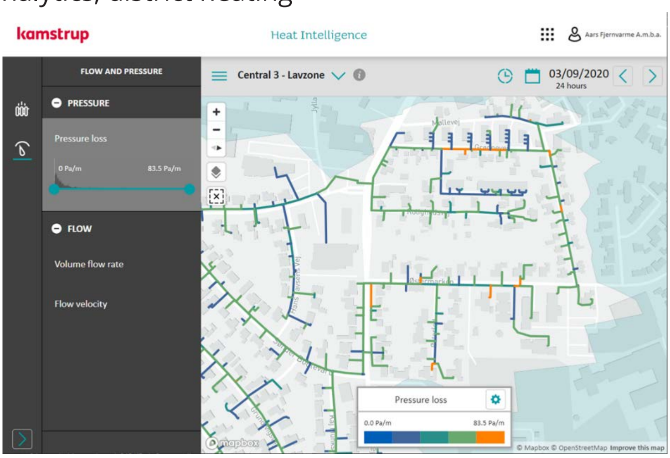
The Heat Intelligence analytics platform from Kamstrup, provides the possibility to add data driven decision support to asset management. Heat Intelligence combines incoming meter data, with data from the GIS system, to continuously estimate the state of the distribution grid with respect to flow conditions, temperature and pressure.

The user friendly map-centered interface, allows Heat Intelligence to provide an easy overview of all parts of the energy distribution system, and an easy identification of regions in the distribution grid with low supply quality, e.g. low supply temperature or flow bottlenecks.

Additionally, Heat Intelligence provides more complex insight such as flow dynamics in network loops with potential dead spots, high heat losses which may indicate leakages or degraded pipe insulation, or identification of unnecessary bypasses. This is all valuable input for asset management, when planning an expansion of the existing distribution grid, or for optimization of the distribution system.

The focus here will be the soon-to-come network pressure analysis module in Heat Intelligence, which is now being tested by selected utilities. This adds pressure meter data to the existing model, and thereby introduces the possibility for a more precise identification of regions with supply challenges, e.g. pipe sections with high pressure losses or regions with low differential pressure. Results from the utilities running the pressure pilot versions will be presented.

Keywords: Data driven, asset management, planning, meter data, GIS, distribution, analytics, district heating



Heat Intelligence pressure module, indicating pipe sections with high pressure losses which may result in low supply

Abdulraheem Salaymeh is Research Associate specializing in the development of heat supply concepts. Experienced with the renewable energy and waste heat recovery technologies as well as with the modelling and optimization of heating networks.

Determination of the district heating supply structure based on geospatial and statistical data

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A clear strategic path to achieving the ambitious climate protection goals in the heating sector is the transformation of the district heating supply and the increase in the share of renewable energies. This was emphasised in the "Strategy on Heating and Cooling" of the EU Commission, among others.

Information on the structure and location of existing district heating networks is generally not publicly accessible for data protection reasons. However, this information forms the basis for the decarbonisation of the district heating supply via sector coupling of electricity and heat. By using this information in addition to data from citywide and building-specific heat demand assessment, it is also possible to determine and locate potential for expanding heating networks.

This thesis presents a methodology for determining the locations and structures of existing and future district heating networks in Germany based on geospatial and statistical data.

Keywords: Heat cadastre, open data, Census, District Heating System, energy system modelling

Martin Santa Maria’s work at iSPACE focuses on modeling spatial energy systems and providing modeling services via Web services.

District heating system optimization with RIVUS, Case study Salzburg

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In a new construction project in the federal state Salzburg, the network-planning tool RIVUS is used for spatial energy planning. RIVUS is one example of network optimization tools, which differ in the spatial scope, level of detail or software surrounding. RIVUS is characterized by its high degree of adaptability, which allows to consider planned building and infrastructure stock in models. First scenarios on possible network setups for the district have been calculated outlining a feasible location of a planned heat plant with minimal overall system costs.

Keywords: Spatial energy planning, Optimization, RIVUS

David Schmidinger is a researcher at e-think. His research areas are modelling of refurbishment in the building sector, strategic heating, and cooling planning as well energy modelling. David Schmidinger works in the field since 2017 and holds a bachelor's degree in electrical engineering and Information Technology at the Vienna University of Technology and is currently working on his master thesis with focus on building renovation.

Assessment of future heat demand and supply with the HOTMAPS toolbox: A case study for San Sebastian

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The following abstract describes how the **Hotmaps project** is used to develop different scenarios for heat demand and supply on the case study of San Sebastian. Therefore, different calculation modules are used to evaluate different parts of the scenarios. In the result section several different scenarios and the overall findings are discussed.

The way we organise heating and cooling demand and supply has a high impact on the energy demand and related CO_2 emissions of a country, region or city. Furthermore, heating and cooling together currently account for around half of the energy demand and the related CO_2 emissions in the EU. Therefore, heating and cooling systems have to change radically in the near future in order to reach low carbon energy systems by 2050.

In order to assist public authorities, planners and consultants in the analysis and strategic planning of low carbon heating and cooling systems the open source planning software Hotmaps has been developed. The Hotmaps project hereby has set up a default database containing heat and cold related data for all EU28 regions, various calculation modules to analyse different parts of the heating and cooling demand and supply systems and a platform where both components can be used. In addition, the Hotmaps database and toolbox is demonstrated in course of the project. For this, heating strategies for several pilot areas around Europe were developed using the database and toolbox.

The aim of the heat strategies in the pilot areas is to identify economically feasible future heat demand and supply systems in the cities with low CO_2 emissions. In this contribution, we describe the starting situation, the analyses performed and the recommendations derived for San Sebastian (ESP), one of the pilot areas.

The first step in the analysis was to collect necessary input data. This consisted of data on existing buildings and related heat demand, the current heat supply technologies and energy carriers used and potentials for renewable energy and excess heat in the region. This also included technical and economic data on renovation measures in buildings, on heat supply technologies and on energy carriers. Hereby we used as much data as possible provided by the local authorities of the city. If no local data was available, we used default data contained in the Hotmaps database and discussed it with the local authorities.

In a second step we developed a toolchain for using the different calculation modules (CMs) contained in the Hotmaps toolbox (see figure 1). The goal was to use the CMs for a) analysing the sensitivity of costs and emissions in the different parts of the heat demand and supply side, and b) generating scenarios for the cities. The toolchain hereby consists of the following steps:

1) Calculate the costs and effects of heat savings in the buildings of the city for pre-defined overall saving targets using a cost curve approach. 2) Calculate the costs and zones of district heating in the different heat saving scenarios in dependence of various influencing factors like share of buildings connected in the zones and maximum allowed distribution costs for single buildings. 3) Calculate the costs and emissions of decentral heat supply in the different types of buildings under the different heat saving scenarios, and 4) calculate the costs and emissions of heat supply to the district heating systems using various different supply portfolios using a dispatch model.

From the calculations for the different parts of the heat demand and supply systems described before combinations of calculations are selected in order to form scenarios of heat demand and supply for the entire city. For these scenarios, we calculate the overall energy demand, the share of renewable energy sources, the overall costs and emissions as well as the heat supply costs. Based on these indicators we derive recommendations for future heat demand and supply in the city.

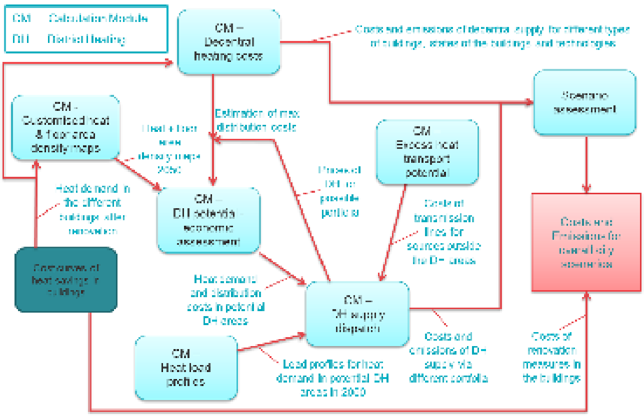

Figure 1: Hotmaps toolchain for calculating scenarios of future heating demand and supply for the city

Our results show, that economic savings in heat demand due to building refurbishments add up to 35% - 40% of the current heat demand.

40% - 50% of the remaining heat demand should be supplied by district heating for cost optimal solutions under the assumptions of our scenarios. Here we see a big sensitivity in the market share, the portion of users which are connected to the grid in a district heating area.

The district heating supply dispatch calculations show a big potential in the near waste incineration plant. It could be economically connected to the district heating net with a transportation line. Another big part of the demand could be supplied by the waste water treatment plant in combination with a heat pump. The remaining peak load would be covered with a biomass boiler to reach low CO_2 emissions. And with an additional heat storage the amount of biomass could be further reduced.

Keywords: Geographical information systems (GIS) for energy systems, heat planning and district heating

Giulia Spirito has a Master of Science degree in Energy Engineering from Politecnico di Milano. She has developed a master thesis work about the potential role of 4GDH in future energy scenarios supporting the municipality of Milano

Potential diffusion of renewable based 3GDH and 4GDH assessment through energy mapping: a case study in Milano

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This work aims at developing a potential analysis of the diffusion of renewables based low temperature DH, through the mapping of energy demand and waste heat sources using the Italian city of Milano as a case study. This goal is to see what would be the future sustainability of DH with the foreseen building refurbishment and consequent heat demand reduction. The feasibility is based on the mapping of available waste heat sources in the city namely, industries, waste water treatment plants, metro stations, datacentres, and ground water wells For the current residential heat demand of, results show that 6TWh could be potentially covered by DH, out of which 80% at same or lower distribution costs than the existing DH. Considering the future energy reduction due to the refurbishment of 60% of the building stock in 2050, the estimated needs for this fraction of refurbished buildings amounts to 5TWh out of which 2TWh can be fed by low temperature plastic network at the same distribution costs of current 3GDH.The reduction of temperature characterizing 4GDH systems opens the door to a wider set of low temperature heat recovery: the outcomes of the mapping and quantification of these sources shows a potential of 4.5 TWh of recoverable heat in the city which increases to 5.2 considering also the surrounding suburbs. The outcomes of this works strengthen the results of Stratego projects concerning the Milano synergy region and it emphasize them by widening the range of heat sources.

Keywords: 4GDH, waste heat recovery, renewables, energy mapping, potential analysis

Institutional and organisational change for smart energy systems and radical technological change

Gatis Bazbauers is a professor at the Institute of Energy Systems and Environment at Riga Technical University. The main research interests are district heating systems, energy system analysis and planning, energy economics and policy development, sustainable energy systems, system dynamics modeling of energy systems

Linking energy efficiency policies toward 4th generation district heating system

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The need to reduce the temperature of district heating (DH) has been a widely discussed solution for moving towards the energy efficient and carbon neutral heat supply system. It allows to achieve a reduction of heat loss and increase use of the low-potential heat. Implementation of 4th or 5th generation district heating system needs a complex solution as it involves the all main elements of DH – an energy source, a heating network and consumers. Retrofitting of buildings and energy efficiency level have been the main factors defining an implementation of the low temperature heat solutions. When evaluating the national heat supply system, it is difficult to evaluate the readiness of buildings to accept lower temperature heat carriers. Therefore, the system dynamics (SD) modelling approach has been used to determine the links between different elements of 4th generation district heating system in the long-term perspective. The overall linkages and assumptions within the model allows to forecast the potential of 4th generation district heating in the future at the national level. The developed system dynamic model allows to evaluate whether the allocated financial support is sufficient for reaching the set energy efficiency goals, as well as to achieve the desired performance of DH systems. Cost-benefit analyses have been performed in order to evaluate different policy scenarios. Sensitivity analyses are conducted to determine the main variables affecting the obtained results.

Keywords: 4th generation district heating; energy efficiency; building retrofitting

Andrej Guminski is a research associate at the Research Center for Energy Economics (FfE). His research focus is the European industrial energy transition, with focus on the electrification of industrial process heat.

Holistic evaluation scheme for industrial greenhouse gas abatement measures – bringing together research and practice

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In this paper, we develop a multi-criteria evaluation scheme (MCES) for industrial greenhouse gas (GHG) abatement measures. The MCES expands the concept of static marginal abatement cost-curves (MACCs) [1] by including regulatory, societal/political and ecological criteria as well as further technical and economic aspects not covered by MACCs [2]. The MCES addresses companies in the manufacturing industry and policymakers. In both cases, the MCES supports the user by listing a holistic set of evaluation criteria. Furthermore, it provides suggestions and application guidelines about methods required which can be used to evaluate each criteria. The evaluation scheme includes both quantitative (e.g. static and dynamic greenhouse gas abatement costs, changes in the use resources and materials) and qualitative criteria (e.g. employee health risks, influence on product quality) [3], [4], [5], [6]. The full set of criteria including specifications is identified through literature research. It is subsequently validated through interviews with stakeholders from the industry, policymakers, civil society representatives and researchers. Special attention is paid to criteria which can lead to the exclusion of a measure from further analysis (e.g. life-cycle emissions are higher compared to reference system). The MCES is ultimately applied to an exemplary industrial electrification measure.

Keywords: Greenhouse gas abatement, industry sector, multi-criteria analysis

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How much to invest? Balancing investment costs and economic benefits of reducing the temperature levels in existing district heating networks

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Decreasing the temperature levels in district heating networks is commonly seen as an important step towards climate-neutral district heating supply systems (Lund et al, 2018). To decrease the temperature levels in existing district heating networks, utilities need to balance, from an economic point of few, investment costs required to lower temperatures and the economic benefits of decreased temperature levels. Generally, valid numbers for these benefits cannot be given, as they are strongly impacted by the existing district heating net configuration (Averfalk and Werner, 2020). Also, upgrading a few customers has only a very low impact on the temperature levels and thus benefits are often not seen by utilities. In our paper, we present the results of a spreadsheet tool, developed to estimate the economic impact of decreasing temperature levels. The tool considers costs and earnings triggered by changes in the distribution losses, electricity consumption for network pumps, production efficiencies, and changes in the shares of heat supply technologies. Furthermore, the economic impact of side effects such as reduced heat demand, which typically come along with optimizations at customers' sites, the benefits of increased network transport capacities or increase pit storage capacity are evaluated. An outcome of the tool are the break-even investment costs for improvements, representing the upper threshold to ensure that district heating costs lower than in the status quo.

Keywords: district heating, temperature reduction, cost-benefit-analysis, building installation optimization

Robert Pratter is working at 4ward Energy Research since 2017, where he is involved in the execution of different energy related projects (district heating, system modelling, heat pumps, etc.). Before that he has studied Mechanical Engineering and Business Economics at the University of Technology in Graz.

HEATflex: Development of a common technical & economic strategy to increase the competitiveness of CHP & district heating plants

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Based on the new "Renewable EU Directive" the decentralized feed-in into district heating systems should significantly be increased by liberalizing the market. So called heat-prosumers and flexibility possibilities will emerge. There interventions in district heating grids have significant effects on operation and control as the pressure and temperature conditions can change significantly. Additionally, new business models are necessary to exploit the prosumer and flexibility approach and to reduce the dependency on subsidies. Therefore, the objective of the Austrian & Danish R&D project HEATflex is to develop a common technical and economic strategy to increase the competitiveness of CHP and district heating plants by providing heat flexibility through the following two approaches, that are linked to each other:

- Centralised generated heat flexibility: CHP + direct linked heat pumps
- Decentralised generated heat flexibility: Heat prosumers through a new developed heat substation + direct linked heat pumps

Furthermore, the project aims to investigate how heat from other processes (e. g. industry, data centers, cogeneration with cooling, excess of energy) can be recovered. A practical guideline for centralized and decentralized generated heat flexibility (technical, economical, legal, implementation, business models) as well as a roadmap for the implementation, planning and engineering of a flexible district heat supply will be developed.

Keywords: district heating, flexibilities, renewable energy, waste heat, heat pump

Callum Rae is a Research Associate conducting research into deployed Smart Local Energy Systems as part of the EnergyREV consortium, which consists of 22 UK institutions. Callum has industrial experience in energy systems modelling and design, and his work focuses on technical barriers to upscaling.

Practical learnings from deployed Smart Local Energy Systems: technical barriers to scale-up

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As the transition towards a more sustainable, distributed energy model has gathered pace, the number of Smart Local Energy Systems (SLES) projects has increased. Ranging in age, size, location and complexity, these projects have enjoyed varying degrees of success, having faced a series of technical, social, economic and regulatory challenges. As such, these deployed projects represent significant – and often under-utilised – sources of practical experience and expertise that can inform the design, development, operation and regulation of SLES in future. By capturing this latent knowledge and feeding it back into academia, industry and policy, this research aims to inform best practice and help mitigate the barriers preventing the wider adoption and scale-up of SLES. This paper presents the results of a systematic analysis of the technical barriers faced by deployed SLES projects in the UK. This consists of a review of literature and UK local energy projects, which are then used to inform a series of semi-structured interviews with technical stakeholders at selected multi-vector SLES case studies. The findings identify a series of key barrier areas, including those posed by multi-vector integration, energy storage, smart technology and electric vehicle integration. A more detailed understanding of site and context-specific barriers – and the relationships between them – is required to facilitate the removal or reduction of technical barriers to the upscaling of SLES.

Keywords: Multi-vector systems, barriers, upscaling, future systems, case studies

Leon Joachim Schwenk-Nebbe is a PhD student at the department of engineering at Aarhus University. He holds a M.Sc. in physics and has multiple years of industry experience in the field of energy economics. His current research focuses on the decarbonization of energy systems.

CO2 quota attribution effects on the European electricity system

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Anthropogenic climate change sets our electricity systems up to new challenges which require us to rethink fundamental concepts of collaboration. Strong benefits and synergies arise when intertwining electricity systems and grids across borders. Countries can both collaborate by extending interconnection capacities, varying their degree of self-sufficiency and by trading emission certificates, or equivalently attributing the burden of emission reductions in different ways among one another. We investigate a near future European electricity system in which the primary source of emission-neutral electricity is produced by variable renewable energy sources, but which also includes current and planned nuclear, coal and lignite power plants. This is combined in a hybrid green/brown field approach. We show that different CO2 emission attributions have an immense effect on the required local CO2 prices. Furthermore, we investigate how this influences the technology mix in the individual countries. We show which countries benefit from broad collaboration and which are better off keeping to themselves.

Keywords: Renewable energy systems, Emission reductions, Local self-sufficiency

Daniel Møller Sneum is a PhD and former analyst in IEA, Green Energy and PlanEnergi. He holds a postdoc in the Energy Economics and Regulation-group at DTU. Research focuses on how district energy can be part of the green transition, through regulation and flexibility.

Flexibility in the interface between district energy and the electricity system

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Economic and environmental benefits of energy sector integration have been thoroughly demonstrated for the interface between electricity and district energy (local heating, cooling and potentially electricity): District energy can help integrate large shares of renewable energy. While the potentials have been clearly demonstrated, integration is not always happening. This study explores the many different barriers for flexibility in the interface between district energy and the electricity system. The study (based in a PhD thesis) presents a review of the literature on barriers, interviews with stakeholders to determine real-world presence of barriers and a series of model-based analyses of selected barriers. Outcomes show 40 potential barriers to flexibility in the interface between district energy and the electricity system. Interviews with 10 U.S. district energy plant managers identify 18 barriers and indicate that district energy plants are an under-utilised asset for flexibility in the U.S. Techno-economic analyses of generic plants indicate limitations to especially power-to-heat in the Baltics and Nordics. Finally, measures to constrain biomass-use, with the intention of increasing power-to-heat, is analysed for the Northern European energy system. Beyond the quantification of barrier-impacts, the study provides a useful toolbox for identifying and addressing barriers to flexibility in the interface between district energy and the electricity system.

Keywords: flexibility, barriers, district energy, US, Nordics, Baltics, regulation, economics, modelling

Karl Vilén investigates the heating system when the housing in Sweden is expanded and where climate targets shall be achieved. This involves system modeling of the heating system as well as analysis of how actors interacts and the ongoing technology and knowledge development in the area.

The Impact of Climate Policy on the District Heating System in a Nordic city

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Sweden has announced plans to have no net emissions of greenhouse gases in 2045, but different Swedish cities plan a much earlier phase-out of fossil fuels in their district heating (DH) systems. Thus, this study investigates two different types of policy for phasing out fossil fuels in the cities´ DH system, either by the introduction of a fossil fuel ban, in 2030 or 2045, respectively, or by an increasing carbon tax resulting in the phase-out of fossil fuels use in 2030 or 2045, respectively. The study, based on using the City of Gothenburg as a case, addresses how these different phase-out strategies may impact the cost-efficient development of the DH system and, in particular, the cost-efficiency of DH in new housing categories (apartment and single family-housing of different sizes and energy standards). The study has been carried out by developing and applying a TIMES cost-optimizing energy system model to the DH system of Gothenburg. The results show that the total amount of heat supplied by DH is not affected by the type of fossil phase-out policy. Further, there are no differences concerning which types of housing that are connected to the DH system. The amount of fossil fuels used to supply the DH system is, however, dependent on what kind of phase-out policy that is implemented. Furthermore, the carbon tax level needed to phase out fossil fuels is highly dependent on the future electricity price, where a high electricity price also requires a higher tax level.

Keywords: District heating, Climate policy, Housing, Passive housing, Energy system modelling

Dr. Behnam Zakeri is a Research Scholar at International Institute for Applied Systems Analysis (IIASA) and a Visiting Lecturer at Aalborg University, Denmark. His research focuses on the role of emerging energy solutions and enablers of energy transitions. He's the Coordinating Author of the IIASA-ISC Initiative on Bouncing Back more Sustainably, which deals with the implications of COVID-19 for sustainable energy transitions.

Aftermath of COVID19 and the Energy Sector: Is a green recovery from economic slowdown possible?

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The global lockdown due to COVID19 has reduced industrial activities, tourism, demand for consumer goods and material, and mobility. This has impacted many sectors of the global economy including the energy sector in short term, resulting in reduced energy demand, low oil prices, disruptions in supply chain of energy technologies and materials, and a decline in investment in renewable energy projects. At the same time, this has led to reductions in greenhouse gas emissions and air pollution.
On the other hand, COVID19 revealed new ways of operating businesses and services by switching to digitalized and online processes, increased remote working from home, reduced business travels etc. While such behavioural and societal changes may not last long once the lockdown measures are reduced, they revealed the potential for transitions in demand for energy services and possibility of structural changes.

The economic downtime due to COVID19 and budgetary constraints of recovery packages have raised concerns on the long-term impact of the pandemic on Sustainable Development Goals (SDGs) and climate stabilization efforts. On the one hand, there is evidence that the pandemic will attract more attention to the importance of science-based decision making and improving the resilience of the human-nature systems, which can accelerate endeavours for combatting climate change. On the other, it is argued that recovering from an economic pressure and progressing climate stabilization, simultaneously, may not necessarily coexist. The priorities of the government in stimulus packages play a big role in allocating new investments, which may lock in nations furthermore in fossil fuel-based economies if not guided correctly. Also, there is a concern that the positive behavioural and lifestyle changes witnessed during the pandemic, like increased use of bikes and reduced aviation, may not naturally lead to a new normal when the urgency of the pandemic is over.

Here, we argue that a green recovery from the COVID19 is not only possible, but it is itself the solution to boost the economy and climate by turning to a "new normal". We review the impact of the pandemic and lockdown measure on the energy system of a set of selected countries. We discuss the resilience of renewable based energy systems in tackling disasters like the pandemic, with focus on three key components of such low-carbon systems, namely, being decarbonized, decentralized and digitalized.

We review the post-COVID-19 economic recovery scenarios to date, evaluating them on how they address the following key questions:
- Energy demand: what are the possible structural shifts in demand for services, and what are their implications for energy use and emissions? what is the role of individual behaviour and consumer choices in a post-COVID19 world?
- Energy supply: What are the structural deficiencies in the energy systems that became evident due to the COVID19 crisis? How the negative economic impact of the pandemic might affect the future of energy transitions (e.g., investment in clean energy industry or enacting phase-out of coal) in developed and developing countries?
- **Energy policy:** what is the impact of recovery pathways on global carbon emissions and on national energy and climate commitments? how do self-centred policies compare versus more international cooperation in the wake of the pandemic?
- **Energy sector and scientists:** How can the role of science and governance in dealing with the pandemic act as an impetus for raising public support for combatting climate change? What is the role of access to open and fair data in assessing behavioural and lifestyle changes (like choices of mobility) and its impact on energy use?

Planning and organisational challenges for smart energy systems and district heating

Professor Dagnija Blumberga leads Institute of Energy Systems and Environment in Riga Technical University. The main research area is energy policy, renewable energy resources and energy efficiency, including 4th generation district heating systems.

How to start the waste heat and boiler house competition in Latvia

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The excess or waste heat from different enterprises have been identified as an important thermal energy source, which can be used for the heat load coverage. The use of surplus heat is possible when there is a careful alignment of potential heat source and heat load. The integration of waste heat is economically justified when the total production costs can compete the costs of alternative technologies (see Fig.1.). The main aim of the research is to develop the methodology for waste heat implementation into the district heating systems by overcoming several barriers. First, waste heat potential mapping eliminates the lack of information. Authors have developed a detailed assessment of largest enterprises, their heat production levels and the distance to the nearest district heating plant. The approach allows highlighting the national technical potential of waste heat. The detailed economic assessment is performed by analyzing the main economic parameters (payback period, investment costs, and primary energy savings) and determine the economic potential of waste heat. In addition, authors have developed several support policy scenarios to compare possible legal frameworks and support initiatives for waste heat integration. Those include the obligations on waste heat integration, the market based business model and the restrictions to install new heat only boilers in the areas with economic waste heat potential.

Keywords: waste heat potential, district heating system, energy efficiency

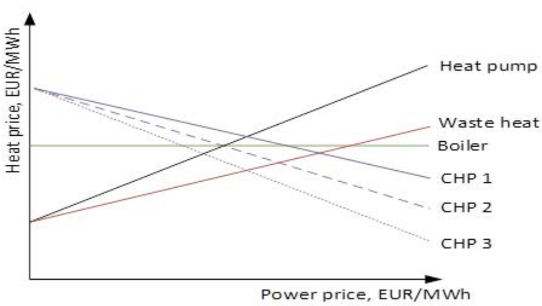

Fig.1. Waste heat potential assessment trough heat and power price levels

Hrvoje Dorotić is research assistant and PhD candidate at the University of Zagreb. His field of interest is energy system modelling and optimization, while the PhD thesis is focusing on district heating systems and natural gas phase out in urban areas.

Cost and Benefits of Shifting Towards Low Temperature District Heating Networks – Energy Planning Approach

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Decarbonisation of energy systems became main goal in recent years. One of solutions to reduce fuel consumption and thus reduce CO2 emissions is shift from high temperature district heating networks (HTDHN) to low and ultra-low temperature district heating networks (LTDHN; ULTDHN). Low operating temperatures, low temperature energy sources and low heat losses are main characteristics of these networks. These low temperatures allow utilization of excess heat, solar energy, water etc. The purpose of this paper is to analyse all network improvements that need to be done in order to shift HTDHN to LTDHN or ULTDHN. Implementation of heat pumps, new network layouts and improved consumer substation are one of them. Also, heated object needs to be more energy efficient to allow use of low temperatures sources. This means that space heating has lower temperatures, around 40 °C, while domestic hot water has temperatures higher than 60 °C in order to avoid Legionella (if no new technologies for avoiding Legionella are implemented). Furthermore, all changes of heat demand, heat losses and utilization of CHP plants are evaluated. Results have shown that by lowering network temperatures heat losses and heat demand are also lowered. All these changes results in desirable network characteristics. Only high investment costs, required for this transformation, can postpone further implementation of these networks, but new discoveries in this field will lower them in near future.

Keywords: energy planning, low temperature district heating, heat loss, heat demand, heat pumps

Leire Gorroño-Albizu holds a B. Eng. in Industrial Organisation and a M.Sc. in Sustainable Energy Planning and Management. Her PhD project is part of EN-SYSTRA, an EU H2020 project funded by a Marie Curie grant programme. Her research focuses on ownership models for 100% renewable and smart energy systems.

How could heat consumers' trust in district heating solutions be enhanced? Insights from Denmark and Sweden

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Fourth generation district heating and cooling (DHC) systems could play an important role in the EU for the implementation of a low carbon energy system with high shares of renewable energy. The proliferation of DHC requires that heat consumers trust in this solution so that they connect (and remain connected) to the local DHC system. Therefore, heat consumers' trust is crucial to reach the heat and cool demand densities that are necessary to make the economy of the DHC system viable and sustainable. However, several countries in the EU are struggling with achieving heat consumers' trust in DH solutions.

This study analyses the interrelations between (1) the institutional framework, (2) heat consumers' power, (3) the fulfilment of heat consumers' interests and (4) heat consumers' trust in DH solutions by studying and comparing the evolution of these four aspects in Denmark and Sweden. These two countries have succeeded in implementing and maintaining rather high shares of DH in their heating sectors, while applying different institutional frameworks. Furthermore, these countries allow for a long-term analysis (over several decades), which makes it possible to study variations in the four aspects mentioned above and to identify key issues and answers. Finally, the study provides recommendations to enhance heat consumers' trust in DH solutions and, in this way, promote the proliferation of these systems in the EU.

Keywords: District heating regulation; consumer's trust; heat consumers' power;

Britta Kleinertz is a researcher and consultant for energy efficiency, successful use of energy management systems and heat supply system transformation. She initiated the first German “District Heating Competence Network”.

District heating supply transformation –Strategies, measures and status quo of network operators transformation phase

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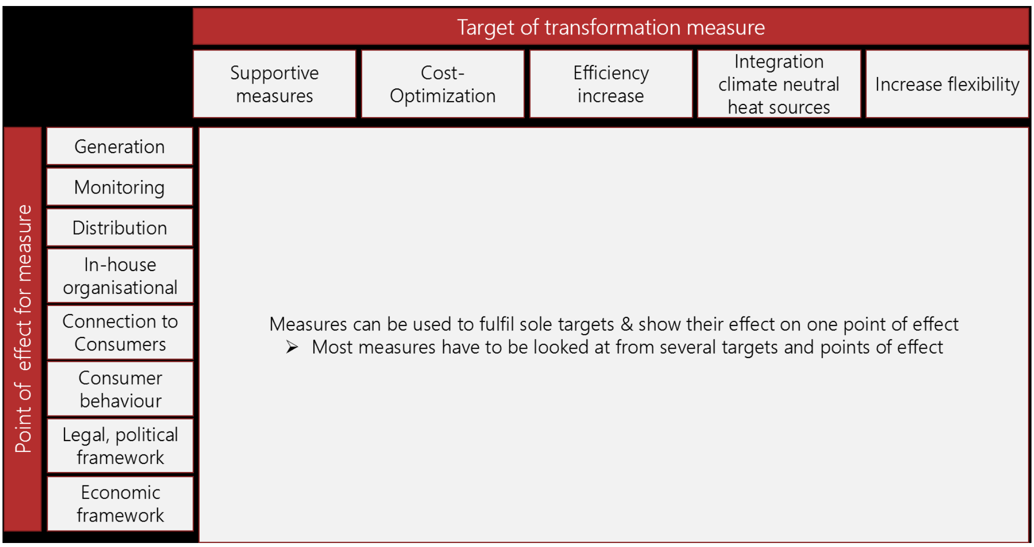
Currently, several cities are developing strategies in order to lower the emissions of their building heat supply to zero. Nevertheless, up to now there is no heating transformation guideline for utilities addressing questions like the stepwise transformation process or the cannibalization of district heating and gas networks. In the “District Heating Competence Network” (DHCN) ten utilities cooperate to make progress in developing a transformation strategy for their district heating network. The three-year project starts with a profound status quos analysis of each utilities transformation strategy. In this research firstly, a short overview on literature describing the process of developing a heating transformation strategy for a region and then specifically for district heating networks is given. These approaches are contrasted to findings made in own research. Next, the current phases of the transformation strategy development in which the participants of the DHCN find themselves is described. Afterwards, the focus is on the transformation of district heating, where a suitable structuration method of transformation measures is described and the resulting matrix is filled with examples from literature as well as discussions in the DHCN (Figure 1). This description is followed by an assessment on how these measures should be prioritized in order to reach the most cost efficient district heating transformation.



Keywords: Heat Supply, District heating, Decarbonisation, Energy efficiency, Transformation strategy, Renewable energies, Infrastructure improvement, Literature review, Practical review

Louise Krog is working as a Post Doc in the Sustainable Energy Planning Research Group at Aalborg University. She holds a PhD in "Strategic Energy Planning", where she has worked with local strategic energy planning in a Danish context.

4th generation district heating – the consumers are a key to success

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100% renewable energy systems requires a smart energy system approach where integration across energy sectors are crucial for the implementation of cost-effective solutions in energy technologies. It is necessary to re-think the concept of district heating(DH) to utilize more renewable energy resources. This paper takes departure in the transition to 4th generation district heating(4GDH) based on low-temperature DH(LTDH). The transition to 4GDH allows new low-temperature energy sources in the DH system. 4GDH also depend on changes on the demand-side, such as energy efficiency improvements in buildings' envelopes and heat installations to support a switch to LTDH. Studies show that energy renovations are conducted at a slow pace and that it is often not feasible to invest in energy renovations under the existing tariff and financing conditions. This paper presents lessons learned about consumers' motivations to implement measures for energy savings within their homes. Through a qualitative study, based on interviews with DH consumers and practitioners, this study investigates which measures can be put into place to motive consumers to carry out energy renovations. The results indicate an interest among consumers to act in relation to energy savings. The economic feasibility is one of the important aspects, but also other important issues for building owners are a lack of individual guidance and differing and sometimes contradictory advice from craftsmen and energy auditors.

Keywords: 4th generation dirstic heating, consumers, consumer involvement

After Stefano Morgione completed his Master's Degree in Energy and Nuclear Engineering, Stefano Morgione has joined Optit, where he works as Energy Consultant within the District Heating industry, supporting digital innovation and system optimization in strategic and operative processes.

A comprehensive framework for District Energy Systems Upgrade

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District Energy Systems have a great role to play in achieving increasingly challenging EU and global climate goals. Yet, large and small systems exist across Europe and their improvement represent an opportunity to achieve significant benefits with relatively small investments. At the same time, guiding their transition towards state-of-the-art standards is key to the reputation of the industry as a whole. The H2020 project UpgradeDH, formed by a very heterogeneous Consortium involving partners from all over Europe and different sectors of the DH supply chain, aims to demonstrate the impacts of best practices on various DH systems, proposing a systemic approach to DH upgrading which could be easily adopted and scaled up across Europe. Key challenges regarding energy generation, distribution and consumption are tackled, sharing knowledge amongst all partners, and suitable practical solutions applied to improve systems' performances. Integration of renewable sources, promotion of sector coupling through storages and advanced digital tools, pumping and other operational optimization approaches are being applied in a variety of contexts, achieving multi-energy integration, full exploitation of existing assets and reduction of energy losses, operative costs and GHG emissions. A sound technical approach is integrated by business models and wider regional action plans designed to ensure overall sustainability and set replicable approaches to support the growth of modern DH.

Keywords: Upgrading, digitalization, smart energy systems, flexibility, sector coupling, efficiency increase, generation, distribution, demand management, losses reduction, replication, action plans

Matteo Pozzi is Partner and CEO of Optit. MSci in Physics and Diploma in International Relations, he spent more than 15 years in management consulting. In Optit he leads the development of a suite of Decision Support Systems based on Advanced Analytics and Optimisation for the DHC & Energy Industry

Supporting Electricity Trading towards XBID implementation through innovative District Energy plant management

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District Energy Systems are evolving towards increasingly complex portfolios, where “traditional” CHCP is enhanced by integrating additional assets, such as waste/renewable heat sources, heat pumps, storages, chilling units, and so on. These systems are managed within a sector coupling framework with electricity buy/sell decisions made according to hourly energy market prices. Managing plant operations requires smart tools that resort to advanced analytical techniques for the optimization of electricity and heat production, while respecting all technical, regulatory, environmental and operational constraints. Optit is evolving its Plant Optimization suite in order to allow seamless integration with Electricity Trading Management, including not only day-ahead, but also intra-day and capacity markets, moving towards a platform compliant with XBID regulations, where electricity will be object of continuous trading. Leveraging on the experience with a leading Italian Utility, Optit will present the many challenges and resolution strategies required to manage the substantial complexity emerging from often diverging business objectives. The project will constitute a compelling case for supporting the next generation of integrated energy management through new paradigms enabled by innovative digital solutions.

Keywords: Modelling, CHP optimization, energy mix, heat generation, digitalization, XBID, enegy trading, energy coupling

Saeid Charani Shandiz is a PhD candidate at University of Melbourne. He graduated from Polytechnic University of Milan with a Master of Science with cum laude in Building and Architectural Engineering. He has worked as building energy engineer and research fellow in Buildings' Environment and Energy Systems.

Towards net-zero emission and energy resilient communities: a multi-dimensional approach to energy master planning

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The development of net-zero emission building clusters is needed to reduce emissions in the building sector. A systematic approach is required to facilitate decision-making processes in the energy master planning (EMP) of net-zero emission communities (NZECs), with district energy (DE) system being a key. This paper presents an EMP framework and methodology for NZEC. The multi-dimensional approach to EMP of NZEC is based on a set of assessment metrics dealing with engineering/technical, economic and environmental issues and a database of technology solution options from the literature and experts' knowledge. The framework clarifies the definition and scope of key parameters relevant to EMP for NZEC. The EMP methodology is applied to the University of Melbourne campus as a case study community to investigate the energy supply solutions towards a 2030 net-zero emission target. The potential energy, emissions and water savings together with the capital and operational expenditures and energy resilience related to each solution are compared in the matrix of results. The integrated EMP methodology presented in this paper will be applied to different types of communities in order to provide guidance to key stakeholders for wider implementation of effective sustainability outcomes. In the era of climate change and increasing urbanisation, this research will facilitate the fulfilment of communities' clean energy objectives by focusing on the new generation of smart and DE systems.

Keywords: Zero emission community, energy master planning, energy resilience, district energy system, performance-based decision-making, operational CO2 emissions, sustainable cities and communities

Tars Verschelde is a PhD fellow at the KU Leuven under the supervision of professor William D'haeseleer. Tars works on a methodology to further understand and improve decisions regarding the implementation of thermal networks.

Case studies on a decision support tool for thermal networks

Tars Verschelde, KU Leuven; William D'haeseleer, KU Leuven

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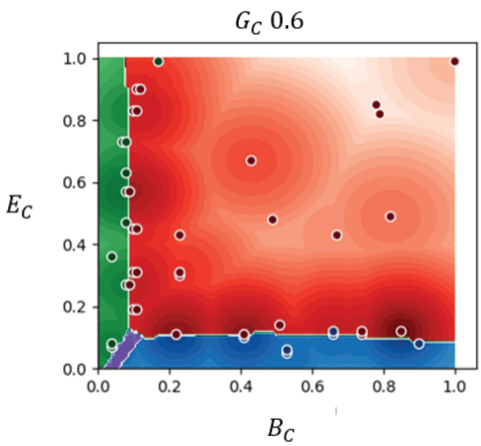
Thermal networks seem to be a promising technology for helping to reach the European climate targets. The potential has been well established for a multitude of regions. However, there is more to learn regarding the quantity and behaviour of the boundary between the use of thermal networks and competing alternatives.

To search for those boundaries, an energy system planning model is optimally sampled for different situations. The model selects the best technologies based on economics (including external costs of carbon emissions). The generated samples are optimised by means of machine learning to concentrate the samples around the as yet unknown boundaries. The final location of the boundaries is then predicted from the optimised set of samples, also with machine learning.

This study highlights some cases with chosen technologies. Initially the option for thermal networks is of interest, meaning that there are two classes of solutions: solutions with and without thermal networks. Next, the case is expanded to multiple classes, e.g. splitting the solutions without thermal networks in solutions with individual heating technologies such as biomass boilers and heat pumps. The cases also reveal a weakness of the used approach; in contrary to random sampling, the samples have to be optimised again if the classes of solutions are changed. Though once the classes of solutions are set, the used approach is very effective.

Keywords: Thermal networks, decision support tool, energy system planning model, global sensitivity, machine learning



Decision boundary for solutions with thermal networks (red), solutions with individual biomass boilers (green), solutions with individual heat pumps (blue) and solutions with a mixture of technologies (purple).The dots are the calculated samples. The gradient shows the distance to the nearest calculated sample for each point. Dots can appear in the incorrect region because this is a projection of 5 parameters to a 2D figure. This is a showcased example with high availability of geothermal heat, a high linear heat density and high gas cost for varying electricity and biomass costs. Obviously district heating is then applied as much as possible until one of the technologies become really cheap. This can be repeated for less obvious cases with different parameters and technologies.

Special session on Innovating SMEs

Hans Joergen Brodersen is a M.Sc. in International Technology, Energy and Environmental Planning from Aalborg University and currently Senior Project Manager at Energy Cluster Denmark . He has worked as External Lecturer at AAU in Technology Assessment and Energy and Environmental Management Systems, prior to, he held more positions as both Private consultant and senior consultant at Deloitte in Business Management Systems and as a Certified Auditor.
He returned to AAU as a Head of Center for Human Appliances and Technology a Cross-departmental business unit for Business/University collaboration, and later for two years Head of the Danish WaveEnergy center focusing on the Sea Testing of Wave energy converters and devices. Technological Energy and Environment planning and development has been his profession since graduation and therefore before joining Energy Cluster Denmark he also worked as senior Consultant at Hydrogen valley aiming at introducing Green hydrogen into the Energy System. He is also the father to three grown up children, and believes the Smart Energy Systems and a green Energy transition has to be sped up to save the globe for the next generations.

Turning SME ideas into New Smart Energy Solutions

Hans Jørgen Brodersen

Energy Cluster Denmark is a cluster with 400 members, including SMEs, OEMs, Universities encompassing in the total energy sector in Denmark.
The cluster is initiating projects for the Green transition of the energy sector , with Sector coupling, system integration, energy Storage, energy-effectiveness, digitalization and power electronics, energy production, transport. ECD wants to develop state of the art projects together with the Industry/sector where the major part are SMEs, that has proven very innovative and agile to the transition. By applying for Funding from both public and Private investors and grant-programs ECD wants to secure that Denmark is at the forefront of green innovating energy transition. A report by the Cluster has found that the SME sector is very large and spread across the country, but also that they have a close cooperation and wish to engage in R&D projects with all 5-6 Danish Universities, public authorities, OEMs, research and development organizations. Examples of the Innovating SMEs are given.

Biomass treatment - How to turn a problem into a resource

Henning Schmidt-Petersen

AquaGreen is a Technology company within the Clean Tech industry. AquaGreen has, together with DTU (Danish Technical University) developed a new and innovative solution for biomass and wastewater treatment and for converting biomass into thermal energy and fertilizer. The patented technology is based on combining superheated steam drying with pyrolysis in an energy efficient process. The thermal energy is recoverable and can be used for district- or process heating purposes. The residual biochar is rich in plant-available phosphorus, carbon and nutrients and is suitable as an agricultural fertilizer and ensures carbon capture and storage. While supporting 11 out of the UN's 17 world goals, AquaGreen's technology transforms an environmental problem into a resource. The solution is based on four principles, which also constitute the value proposition:

-Rethink – Innovation: Patented technology
-Reduce – Pollutants: Such as environmental substances, Mercury, Arsenic and Cadmium
-Recirculate - Resources: Such as thermal energy, nutrients (e.g. Phosphorus) and biochar oractivated carbon, which will ensure carbon capture and storage.
-Return - On investment: 2-8 years

Market potential
The market potential is global and goes across industries. The potential for the technology within the Aquaculture industry in the Nordic region alone is approx. € 675 Millions. Within the wastewater and biogas industry in Scandinavia and Germany, the total sales potential is estimated to € 11,5 Billions.B The potential is therefore considered to be enormous in a global perspective.

AG has chosen to penetrate the markets step by step and is therefore currently focusing primarily on the domestic market and secondarily on Norway and Sweden. When the technical solution for smoke purification has been developed and commissioned at the first commercial plant, which is expected to be set up at Søndersø Wastewater Treatment Plant, the focus will be extended to initially the European market and subsequently Asia and America.

Technical improvements to be achieved in the project

After having proven the technology, a combustion chamber (burner) that can provide optimal combustion is requested to be developed. Pyrolysis gas is an inhomogeneous fuel source filled with tar substances that require good mixing with air to oxidize optimally. The burner must also be flexible in relation to a varying input of pyrolysis gases as well as comply with legal requirements for residence times at certain temperatures.

Emission of nitrogen oxides (NOx) also has to be optimized. Sewage sludge contains a lot of nitrogen (N), typically 4-6% of dry matter. NOx can be formed in two ways: One is combustion NOx, which occurs if the conditions for oxygen and temperature are right, then NOx is formed by oxidation of the nitrogen in the air (N_2). The second is by oxidation of organic N-compounds or ammonia, which comes from the fuel, this is called “fuel-NOx”. Therefore, a burner must be designed that produces minimal NOx out of the air nitrogen and a flue gas system that reduces fuel NOx emissions so that the statutory limit values are complied with.

Outcome

The expected outcome of the project is an improved, up-scaled burner, which will be used in the up-scaled version of AquaGreen’s solution, which have already been sold to Wate- Water Treatment Plants.

Bo Eskerod Madsen started his carrier as electrician in the country side more than 25 years ago, has down the road gained a PhD in statistical data science from University of Aarhus (Denmark), and University of Auckland (New Zealand), and is now the CEO of ReMoni

Clamp-on Monitoring of Energy from the Outside of Existing Multiconductor Cables and Pipes

Bo Eskerod Madsen (presenter), PhD and CEO of ReMoni

Energy and Production Efficiency is a common challenge in professional buildings and production. The problem is that technical installations tend to break, get out of sync, lack maintenance, or the use of the building simply changes over time.
ReMoni provides data on the single critical device in the building, at any given moment. It enables the Facility Management team to find and fix dysfunctional devices.
Our patented secret is to combine non-invasive sensors with cloud AI, to provide new insight in the consumption of the technical installations. We thereby help save valuable resources, using real-time data and even alarms when something is not running as planned.

Figure 1: The ReMoni IoT Clamp-on sensor mounted non-invasive on the outside of a multiconductor cable.

Keywords: To eliminate loss of energy, production and CO2 in buildings and production

Mario Javier Rincón is native of Segovia, Spain. After his bachelors in Mechanical Engineering in Madrid, he came to Denmark in 2016 to study a masters in Energy Engineering at Aalborg University. Since then, he has been closely involved with the entrepreneurial environment in Denmark and Europe, creating awareness and promoting the transition of new energy technologies.
In 2016, he co-founded FluidTech where he is the Chief Technology Officer. He is in charge of project management from a technical standpoint.

Micro-ORC technology development

Mario Javier Rincón, FluidTech

All processes that either consume or generate power have something in common: they generate heat. Currently, there are not cost-efficient solutions to use that heat so, heat is treated as waste and discharged into the environment. In FluidTech, we believe there is a better solution and the recovery of heat can be democratised and used at all levels. In this project, FluidTech and its partners aim to develop and optimise a Micro-Organic Rankine Cycle system for low-temperature waste heat recovery. This system is based on a simple and efficient thermodynamic cycle able to transform energy from thermal to mechanical and electrical form: a micro power plant smaller than a fridge. Together with Aalborg University, a prototype is built, optimised, and tested in laboratories. Subsequently, the system is tested in a relevant environment from the asphalt industry. However, these are not just some experimental tests. This project is undertaking design and optimisation from a tecno-economic standpoint in order to offer this technology to the market. Not just create a technological proof-of-concept.

Total Building Automatic Energy Management

Bjarke Henriksen

Smartenergi is a small innovative company in Aalborg with a background within photovoltaic systems that works to implement automations between a customers PV system, battery, heat pump, electrical vehicle, air condition, ventilation, appliances and other relevant energy consuming products in a typical residential building.
Today there are no incentive tariffs or other noticeable subsiding programs to enhance photovoltaics in Denmark, but our electricity prices are still high and our society is getting more electrified not only covering normal house hold consumption but also electrifying heating and transportation mostly through heat pumps and EV-vehicles.
Smartenergi not only sells and install the energy management system, but also offer installation of complete PV systems, batteries, heat pumps and EV-charge stations all connected in full automation as a complete package or as single items.
Our goal is to bring down the energy bill as much as possible for private consumers and commercial buildings and leave as little Co2 footprint as possible.
Our vision is to combine local produced PV energy with energy management and differential tariffed electricity to even bring down the electricity bill and Co2 footprint further. We are working with a Danish grid company to make this happen, but we are also looking for more partners to make this work.
We aim is to bring this technology and products into private homes especially new buildings that can be planned from the get-go. Also here we are looking for partners in the residential building industry.
How our product works today:

1. First we need a local energy source such as a PV system or a windmill/turbine.
2. Then we install our PLC into the circuit board.

After here it really depends on the installation and the scope of the building, but:

3. Battery usually LFP or Flow batteries to store renewable energy (in future also from the grid).
4. EV-chargers controlled dynamically (only charge with surplus PV energy and supplemented with grid power if needed)
5. Heat pumps with slightly larger storage heat tanks for both heat and domestic hot water (max. 55 degree Celsius).
6. Dynamic controlled heating rod raises the temperature even further from 55 degrees Celsius in both heat tank and domestic hot water tank (sometimes 2-1 combined tanks).
7. Cooling (air condition)
8. Start signal for IOT appliances (work in progress).
9. Boost ventilation system (option).
10. If swimmingpool or hot tub/spa bath is present then control of circulation filter pump and heating.

11. Boost signal for smart home system such as KNX, Loxonne, Alexia, Google Home, Apple Home, Carlo Gavazzi and other smart home solutions. (this would often be temperature and ventilation control inside the building)

Our goal is to be part of the smart grid were consumer devices such as above products will benefit from own local PV production in combination with a more dynamic controlled electricity grid where data and consumption will be shared and controlled on a larger and more intelligent scale. We believe this will be needed in order to bring down the usage of fossil fuels to an absolute minimum. But we vwill not sit back and wait for “magic” to happen and therefore we offer the first solution that can save the house or building owner a lot of money.
Today this complete solution have a ROI of about 6-10 years or roughly 10-15% yearly capital investment after tax. With very low interest rates and peoples focus to bring down fixed costs we see a rising interest in our products and services.

Amela Ajanovic is Asst. Professor at TU Wien. She holds a master degree in electrical engineering and a PhD in energy economics at TU Wien. Her main research interests are alternative fuels and alternative automotive technologies as well as sustainable energy system and long-term energy scenarios.

Impact of coronavirus crisis on electrification of mobility

Amela Ajanovic, Technical University of Vienna; Reinhard Haas, Technical University of Vienna

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Worldwide, the electrification of mobility is recognized as one of the main strategies for emission reduction in the transport sector. Many governments have set goals to increase number of electric vehicles (EVs) and due to different supporting measures provided by governments the number of EVs was continuously increasing over the last decade but this development was rapidly changed with the spread of coronavirus. The core objective of this paper is to investigate the impact of the coronavirus on EVs across the supply chain starting from the raw materials for battery production up to the car manufacturing. Using our model based on the calculation of total cost of ownership of EVs in comparison to conventional cars and a life-cycle approach, we have analyzed in scenarios future short- and long-term prospects for electrification of mobility from an economic and environmental point of view. Although, electrification of mobility is seen as a way to increase energy supply security, this crisis has shown many disruptions in the EV supply chain and huge dependency from China. The major uncertainties regarding market prospects of EVs are developments of oil prices and speed of technological learning, as well as how the regulatory restrictions for individual transport will look like in future. If more and more cities (such as Paris) are planning to ban conventional diesel and petrol vehicles this might provide a more bright future for EVs.

Keywords: electric vehicles, battery, supply chain, emissions, costs

Nina Detlefsen, Chief analyst in Grøn Energi, holds a PhD in operations research. She has worked within energy system analysis for the past 15 years with focus on the electricity and heating. Her focus is system integration and optimal use of resources, especially how performs towards climate goals.

How electrification of the heating and transportation sector affects the load in low voltage electricity grids

Nina Detlefsen, Grøn Energi / Dansk Fjernvarme

The electricity system is facing enormous investments to increase capacity, both in the transmission and in the distribution system, partly due to electrification of the heating and transport sector.
In this analysis we analyze how the consumption in individual houses affects the load in the low voltage grid. We use data from an area that today is primarily heated with natural gas and the underlying assumption is, that natural gas has to be phased out in the future as a part of the green transition.
If natural gas is not used for heating there is primarily two existing alternatives in Denmark, electrical individual heat pumps or district heating. Both represent an electrification of heating but it will affect the low voltage grid in different ways. This is what we investigate in this analysis.
The starting point is the classic electricity consumption in the individual houses. We have gathered hourly data for 132 households for one year. We will show the resulting loads in the low voltage grid.
Several assumptions are made for future consumption and local production of electricity which will cause households consumption patterns to change:

Electrification of transportation, i.e. more electrical vehicles.
Local production will increase, that is, we expect more photovoltaic systems at individual households.
Electricity based heating is expected to increase (from either individual heat pumps or district heating).
Local flexibility will increase, this includes batteries but also flexible charging of EV's or flexible load of heat pumps etc.

We will analyze the resulting consumption patterns and the consequences for the low voltage grid. Depending on the different solutions it will call for investments in infrastructure and we will discuss the costs of the solutions. We will discuss consequences for consumers in term of annual heating costs including investment. We also discuss the socio-economic costs of the different future heating scenarios including the consequences for the individual consumers.

Keywords: electrification, low voltage grid, district heating, heat pumps, electric vehicles

Christine Gschwendtner investigates how electric vehicles, heat pumps, storage, and distributed generation, can be integrated into distribution networks, using quantitative and qualitative methods. She holds an MSc in Environmental Change (Univ. of Oxford) and a BSc in Environmental Engineering (TU Munich).

Uncertain impacts of technology, infrastructure, and vehicle use types on the integration of Vehicle-to-grid (V2G) into distribution networks

Christine Gschwendtner, ETH Zurich; Annegret Stephan, ETH Zurich

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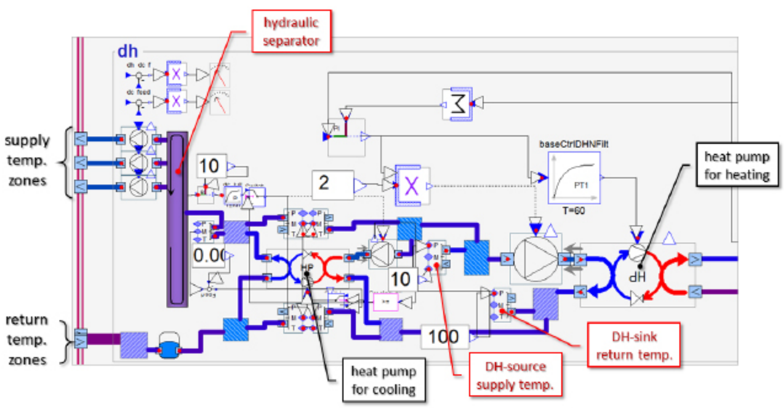
Bidirectional power flows between vehicles and the grid (V2G) could support grid operations at both transmission and distribution level. However, it remains unclear whether V2G can offer the proposed services in practice. This study investigates the integration of V2G into smart distribution networks. We discuss different vehicle use types, and their compatibility with V2G services, considering future changes in mobility behaviour. As we take a practical perspective, we first analyze a V2G trial database to provide an overview of the tested combinations of vehicle use types, V2G services, and charging locations. To gain further details about the trials and V2G development, we conduct 33 interviews with academic and industry experts. We find that the lack of data about current distribution network loads leads to high uncertainty about future flexibility requirements. Additionally, trade-offs and synergies between transmission and distribution services, and the interaction between Vehicle-to-customer (V2C) and V2G need further investigation. The plug-in rate and the charging location are the most important temporal and spatial factors to determine the suitability of vehicle use types. While commercial fleets offer high predictability, domestic vehicles offer higher availability. Further trials should collect real-life data on distribution network loads, plug-in habits, and the reliability of services from different vehicle use types in different networks.

Keywords: Electrification, Vehicle-to-grid, bidirectional charging, charging strategies, mobility behaviour, distribution networks, flexibility



Reinhard Haas is professor at the "Institute of Energy Systems and Electric Drives" at TU Wien, Austria and head of the Energy Economics Group. He has more than 20 years of experience in energy economics, sustainable energy systems, markets and policies and has published more than 80 peer-reviewed papers.

The correlation between variable renewable energy sources and energy demand for heating & cooling

Jasmine RAMSEBNER, EEG - TU Wien; Reinhard HAAS, EEG - TU Wien; Franziska SCHOENIGER, EEG - TU Wien

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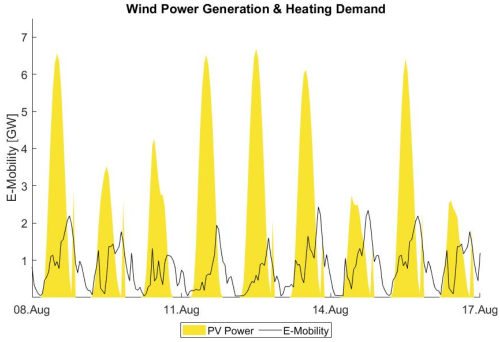
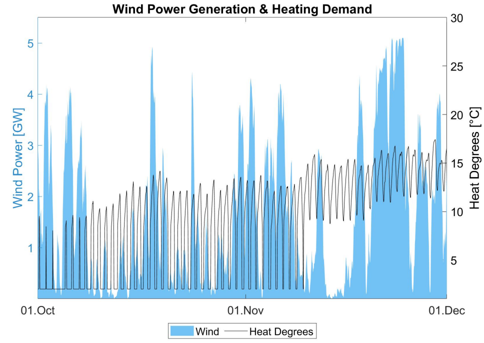
Future energy systems will be characterized by a large share of electricity feed-in from variable renewable energy sources, such as wind and photovoltaics (PV) to achieve the decarbonisation of all end-use sectors. Generation peaks of wind or PV electricity, could directly supply the heating&cooling sector via heat pumps and electric boilers or the transport sector by powering battery electric vehicles (BEV). While wind availability may cause temperature decreases and correlate with heating demand to some extent, solar PV power is expected to correlate with cooling demand during the day. This situation represents potential for short-term, most direct use of renewable electricity.

We analyse the correlation between historic PV and wind electricity generation profiles and the demand expected in future scenarios in the end-use sectors heating&cooling and transport for countries in different climate regions: Germany, Spain and Austria, considering the expected increasing direct or indirect electrification through renewable gas and synthetic fuels. Our preliminary results show that the potential of wind power use for heating is specifically interesting, whereas PV power is expected to correlate positively with cooling demand and is also able to cover some BEV charging during the day, if the cars charge at a public place or at home. PV for heat pumps in heating does not show any correlation and a battery storage would be required.

Keywords: Sector coupling, variable renewable energy, E-mobility, heating, electrification, renewable electricity, wind power, solar power, correlation





Sajjad Haider is a PhD candidate in Electrical Engineering, and has a Master's in Energy from Texas A&M University. He is currently working on measuring the impact of electric vehicle adaptation in low voltage networks, with the aim of inducing behavioral change to reduce negative effects.

Uncontrolled Electric Vehicle Charging in Low Voltage Grids – Impacts

Sajjad Haider, TU Dresden; Peter Schegner, TU Dresden;

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The authors hypothesize that the introduction of EV's will cause significant overloading within low voltage distribution grids. This study focuses on the monte-carlo modelling of the behavior of typical European low voltage, semi-urban networks with 155 individual consumers in three distinct usage scenarios: residential loads, residential loads with distributed grid tied generation of electricity and the same with electric vehicles introduced into the grid. All three cases involve probability-based load models, based on real case data and measurements. Simulation results show critical cables having flexible loading allowances between 15% and 60%, depending on the time of the day. Voltage levels across the various terminals show an average drop of less than 8%, which is typical of low voltage networks meeting German transmission standards. Once 200 EV's are introduced into the LV grid and car charging is time dependent and distributed randomly geographically, upto between 20 and 26 cars are simultaneously charging. This subsequently pushes the average line loading to over 150% due to high instantaneous power demands. Furthermore, maximum line loading for critical lines shows outliers as high as 250%. Voltage drops are observed across the grid, with the average being over 10% and two sensitive nodes showing drops as high as 16% on average and 30% in outlying maximum data during the peak hours.

Keywords: energy, electric vehicles, low voltage grids, voltage drops, impact of EV's

Simon Meunier is currently a postdoctoral researcher at KU Leuven in the frame of the H2020 sEEnergies project. He works on the integration of low-carbon technologies into low-voltage distribution grids.

Towards mapping grid reinforcement costs from residential low-carbon technologies penetration in Europe

Simon Meunier, KU Leuven - Department of Civil Engineering - Building Physics Section - Belgium, EnergyVille - Belgium;
Christina Protopapadaki, KU Leuven - Department of Civil Engineering - Building Physics Section - Belgium, EnergyVille - Belgium;
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Despite its potential to reduce CO2 emissions, the deployment of residential low-carbon technologies (LCT), e.g. heat pumps and solar panels, strongly influences the distribution grid stability triggering potentially significant reinforcement costs. Previously, we have built a detailed techno-economic model, based on power flow analysis and cost data, which computes the required grid reinforcement cost for a given LCT integration scenario. While accurate, the model requires significant computing time and high-resolution inputs (e.g. 10 minutes load profiles for each household), limiting the possibility to simulate and map grid reinforcement costs for each area of Europe and for many integration scenarios.

In this work, which is part of the sEEnergies project, we design a metamodel that relates the grid reinforcement cost to input variables that can be spatially mapped, such as the average annual household electricity demand. A dataset is created containing the potential metamodel input variables and resulting reinforcement cost from application of the detailed model to typical feeders for several integration scenarios. Using cross-validation, we fit and validate metamodels of the cost for different combinations of inputs and several fitting functions. Finally, we present and discuss the performance of each metamodel specification (inputs and fitting function), in terms of prediction capabilities and gains in computing time.

Keywords: distribution grids, low-carbon technologies, techno-economic analysis, reinforcement cost, metamodeling

Adrian Ostermann is a research associate at Research Center for Energy Economics (FfE) since 2018 and holds a M.Sc. in Environmental Engineering from TU Munich. He is currently working on the Project Bidirectional Charging Management where he is responsible for the evaluation of the field trial.

Potential of vehicle to grid charging control of electric vehicles in congestion management

Steffen Fattler, Research Center for Energy Economics (FfE), Adrian Ostermann, Research Center for Energy Economics (FfE)

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The uneven distribution of wind and solar electric generators increasingly leads to grid congestions, which are currently compensated for by short-term measures such as the redispatch of conventional power plants or the curtailment of renewable energies. On the other hand, electric vehicles as a possible CO2-reduction measure in the transport sector are the centre of public and political discussion with targeted shares of 15-20 percent by 2030. This paper examines whether a bidirectional (bd) charging control of electric vehicles can provide the necessary flexibility to reduce the frequency of such congestion management measures. Therefore, the scope of an existing model for the load curve generation of electric vehicles is extended. Based on various traffic surveys, coherent annual driving profiles are compiled. From these, high-resolution charge load profiles of individual vehicles are synthesised. A new charging strategy is implemented allowing an optimization of charging points according to the flexibility demand due to redispatch or curtailment measures in each specific area. The flexibility demand is calculated based on historical plant-specific and time discrete data. The data is merged to coherent and regionally resolved time series of flexibility demand. Based on the methodology the potential of the bd-charging strategy to reduce the curtailment of renewable generation plants and the redispatch of fossil power plants and the resulting ecologic benefit is estimated.

Keywords: vehicle to grid, electric vehicles, res, congestions management, feedin management, ecologic impact

Niklas Wulff studied engineering in Darmstadt and Berlin. He worked and published on critical materials in energy technologies. His work currently focuses on the interface between transport and electricity sector, namely electric mobility and synthetic fuels.

Vehicle Energy Consumption in Python (VencoPy): Presenting and demonstrating an open source tool to calculate electric vehicle charging flexibility

Niklas Wulff, German Aerospace Center; Gils, Hans Christian, German Aerospace Center; Hoyer-Klick, Carsten, German Aerospace Center

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While the value of a flexible electric vehicle fleet has been shown for various scopes [1-4], so far no input dataset for electric vehicle charging flexibility has been published, prohibiting the transparency and reproducibility of scientific studies. We present an open source tool, Vehicle Energy Consumption in Python (VencoPy), that calculates electric vehicle fleets' charging flexibility. The German national travel survey encompasses data from around 1 Mio. trips at the target date. The quantification of trip-specific representativeness weights of each profile allows for a scaling to represent the overall German travel behaviour. [5]
By applying technical scenario assumptions, we demonstrate the calculation of electric vehicle charging flexibility profiles. The concept was first described in [6], further developped and applied in [7].
In our results, we show the sensitivity of electric vehicle charging flexibility on region type, regional scope and battery capacity. Our work will be helpful for energy system modelers in need for technical potentials of electric vehicle fleet charging flexibility in hourly temporal resolution. With opening up code, researchers can reproduce our results and contribute to the codebase of the tool.
Energy system modelling is lacking transparency and reproducibility. With VencoPy, we provide a transparent tool to tackle this shortcoming in the case of electric vehicle flexibility modelling for sector-coupled energy system analyses.

Keywords: Electric vehicles, electricity system flexibility, electric fleet, energy system modeling, open soure, transparency

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Meng Yuan is a PhD fellow at China University of Petroleum (Beijing) and a visiting researcher in the Energy Planning Research Group at Aalborg University. Her current research revolves around the sustainable transformation of the energy system in China, focusing on the modeling and analysis.

The role of transportation electrification in the energy transition of urban agglomerations: A case study of Beijing-Tianjin-Hebei region

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Jakob Zinck Thellufsen, Aalborg University
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Transportation electrification is currently seen as one of the key strategies in the sustainable energy system. This work aims to identify what role the transportation electrification in the urban agglomeration can play for heading towards a sustainable energy system from a medium-long term perspective, specifically analyzing the impacts of electric vehicle penetration in terms of costs, energy consumption, CO2 emission, renewable energy utilization, and interregional collaboration. The Beijing-Tianjin-Hebei (BTH) urban agglomeration is taken as a case study. The energy demand in the road transport sector of the BTH region is forecasted precisely by a bottom-up model with the consideration of vehicle types, economic development, and population growth, etc. Five future scenarios of different strategies of energy system planning and charging modes are simulated with the help of EnergyPLAN software. Results show that the energy system of the BTH region benefits from transport electrification even at a low EV penetration rate. Assuming adopting complete electrification of all types of vehicles (i.e., light-duty passenger vehicles, buses, and trucks) and the smart charging strategy, the energy consumption and CO2 emissions can be reduced by -12.31% and 11.79% respectively in 2050, without significant cost increases. The vehicle electrification also promoting electricity cooperation within the urban agglomeration by increasing the consumption of renewable resources.

Keywords: Transportation electrification, Electric vehicles, EnergyPLAN, Integrated energy systems analysis, Urban agglomeration

The production, technologies for and use of electrofuels in future energy systems

Christian Bundgaard holds a bachelor's degree in Energy Engineering and a master's degree in Sustainable Energy Planning and Management, both from Aalborg University. He is working as a research assistant at the Department of Planning at Aalborg University. His current research is focused on energy system analysis as well as production and implementation of electrofuels for decarbonisation of the transport sector.

System Effects of Implementing Electrofuels for Decarbonisation of the Transport Sector in a Danish Perspective

Christian Bundgaard, Aalborg University; Brian Vad Mathiesen, Aalborg University

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Electrofuels are experiencing increasing attention as a mean to decarbonise the parts of the transport sector not suited for direct electrification, identified as heavy road transportation, aviation, and shipping. The production of electrofuels can be a flexible energy demand, providing necessary flexibility in a future energy system with large amounts of fluctuating renewable energy sources, while not relying solely on the scarce resource of biomass. In this study the system effects of several electrofuel pathways are analysed with varying combinations of production methods and electrofuel output. The analysed types of electrofuels include methane, methanol, ammonia, DME, and synthetic JP, and the analysed production methods include CO2, biomass, biogas, and N2 hydrogenation. The analysis utilises the advanced energy system analysis computer tool EnergyPLAN where a 2030 model of the Danish energy system is modified to include 2,5 TWh of electrofuels. The electrofuel pathways are evaluated against several environmental and economic parameters, where results show that sustainability and economically feasibility vary significantly according to type of electrofuel and production method.

Keywords: Electrofuels, power-to-x, transport

Tobias Hübner workes at the FfE in Munich for nearly three years and is currently doing his PhD on the topic of synthetic fuels in industrial transformation pathways and the impact on the energy-relevant gas infrastructure.

Simulation-based analysis of synthetic fuels in the industry in relation to climate protection level

Tobias Hübner, Technische Universität München, Forschungsgesellschaft für Energiewirtschaft; Serafin von Roon, Forschungsgesellschaft für Energiewirtschaft

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The electrification and the utilization of synthetic fuels play a crucial role in the defossilization of the industry. Especially, the direct and indirect electrification of the industry sector is highly complex and challenging, mainly due to process-specific requirements [1]. In order to achieve almost fully industrial defossilization, the fossil energy consumption remaining after the implementation of efficiency and sufficiency measures, as well as direct electrification is to be substituted through hydrogen and synthetic hydrocarbons. The dynamic modeling of GHG abatement measures with the Sectormodel Industry enables the deriving of holistic transformation paths based on heterogeneous, process-specific development [2]. The transformation paths provide the opportunity to analyze details such as the demand for synthetic fuels in the industry sector, taking into account interactions with other GHG abatement technologies like electrification. This makes it possible to identify the crucial influence factors regarding the utilization of synthetic fuels.

The main results contain quantified parameters and influencing factors regarding the utilization of hydrogen and other gaseous, liquid and solid synthetic hydrocarbons in the industry sector-specific transformation paths.

[1] Lechtenböhmer,Stefan et al.: Decarbonising the energy intensive basic materials industry
[2] Hübner, Tobias: Small-Scale Modelling of Individual Greenhouse Gas Abatement Measures in Industry

Keywords: electrofuels (synthetic fuels), industry modelling, electrification, defossilization, decarbonization

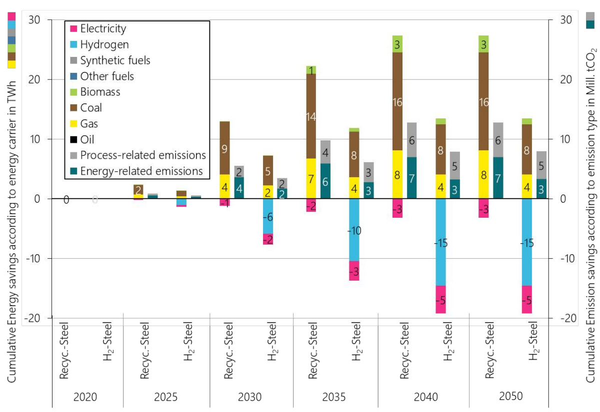

Fig. 1: Changes in energy and emissions as a result of process route changes, lower/higher energy consumption compared to Reference is positive/negative, lower/higher emissions compared to Reference are positive/negative

René Kofler is a PhD candidate at the Section of Thermal Energy, Technical University of Denmark. His research focuses on the thermodynamic modelling, analysis and optimization of energy conversion systems, especially biorefineries, and their integration into the power and heating sector.

Comparison of different biorefinery systems integrating the electricity, heating and transport sector

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For a future fossil fuel free society, the use of fossil fuels has to be reduced in all sectors, including the heat and transport sector. Biorefinery systems address both sectors, as they are able to produce biofuels and heat. Additionally, they can interact with the power system by either producing renewable electricity or using renewable electricity for producing electrofuels through Power-to-gas or Power-to-liquid. In this work, different systems based on the gasification of wheat straw are compared. The wheat straw is gasified in a low temperature circulating fluidized bed (LT-CFB) gasifier, which allows for efficient gasification of agricultural residues. After catalytic upgrading of the produced gas, the contained tars can be condensed and collected as bio-oil. The bio-oil can be further processed and upgraded to liquid fuels like gasoline or diesel. The remaining gas can be used for different purposes. In this work, the following four cases are compared based on their energetic and exergetic efficiency:

a) The gas is burned in a gas engine for producing electricity and heat. The surplus heat is used for supplying high temperature process heat and district heating.

b) The gas is upgraded to synthetic natural gas (SNG). Additional hydrogen is produced through water electrolysis.

c) The gas is upgraded to dimethyl ether (DME). Additional hydrogen is produced through water electrolysis.

Keywords: Biofuel, Biorefineries, Biomass Gasification, Electrofuel, Polygeneration, Power-to-gas, Power-to-liquid, Straw

Xavier Rixhon's thesis consists, on one hand, in integrating electro- & synthetic energy carriers into the Belgian energy system model. On the other hand, to take into account the variability of model input and parameters, uncertainties qualification help to get a robust optimization of the energy system.

The role of electro-energy carriers under uncertainties for Belgian energy transition

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Wind and solar energies, per se, present a time and space disparity which generally leads to a mismatch between the demand and the supply. To harvest their maximum potentials, one of the main challenges is the storage and transport of these energies. This challenge can be tackled by electric-energy carriers. They offer three main advantages: compatibility with existing distribution networks or technologies of conversion, economical storage solution for high capacity (from 100 GWh), and ability to couple sectors (e.g. energy with chemical industry). However, the level of contribution of electric-energy carriers is unknown. To assess their role in the future, we used whole-energy system modelling (EnergyScope TD) to study the case of Belgium. This model is multi-energy and multi-sector. It optimises the design of the overall system to minimize its costs and emissions. Such a model relies on many parameters to represent as closely as possible the future energy system. However, these parameters can be highly uncertain, especially for long-term planning. Consequently, this work integrates a global sensitivity analysis in order to highlight the influence of the parameters on the outputs of interest (e.g. CO2 emissions, cost of the system,...). In addition to the share of these fuels in the future energy system, the results point out the driving factors to their integration. On a larger scope, this study helps policy makers to come up with robust decisions towards sustainability.

Keywords: Electro-fuels, Sectors coupling, Energy system, Global sensitivity analysis, Renewable energies

Mr. Hammam Soliman is Senior Sales and R&D Manager at Aalborg CSP, responsible for the planning and implementation of research programs with the aim to create the technologies of tomorrow. He is Aalborg CSP's strong link to knowledge-based institutions and plays an instrumental role in establishing relationships with the Middle East and North Africa region.
Hammam holds an M.S. degree in Electrical and Control from the Arab Academy for Science & Technology in Cairo (Egypt) and earnt his Ph.D in Power Electronic Engineering from the highly ranked Aalborg Universitet (Denmark).

Contribution of Power-to-X-to Power in retrofitting of Coal-Fired Power Plants

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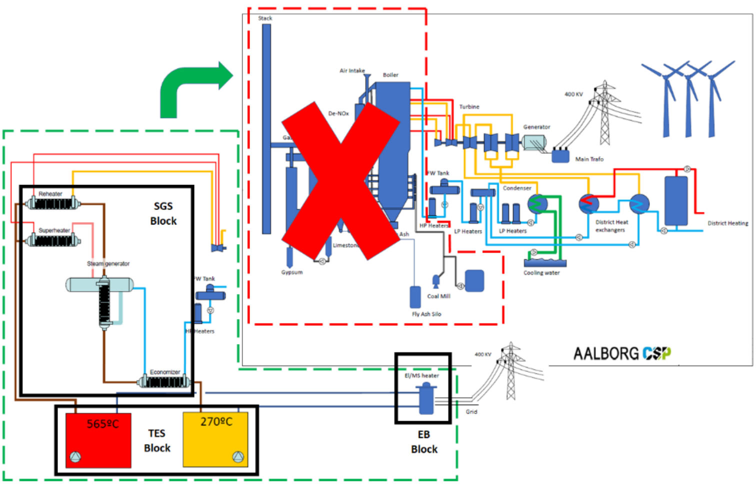
During the past couple of years, Power-to-X-to-Power has been a research and development focal point within the field of renewable energy - with thermal energy storage (TES) as an essential part of the concept. This abstract will discuss the role of Power-to-X-to-Power in the retrofitting of Coal-fired Power Plants (CPP) and present a viable energy storage solution for the remaining Coal worldwide.
The objective is to make a proof-of-concept by using a CPP or a renewable energy supplier (e.g. biomass plants) as a demonstration host to demonstrate the technological and commercial feasibility.



The retrofitting concept, as shown in Fig. 1, includes a replacement of main CPP components such as the boiler and chimney. These are replaced by a package consisting of an electric boiler (EB), a steam generation system (SGS), and a TES system. This package is integrated with the remaining components of the CPP including the STG and high voltage equipment.

Fig. 1: CPP including retrofitting proposal with re-used existing assets.

The proposed solution contributes to grid stability in the following way. Excess power production from e.g. wind and PV is utilized to drive an EB and stored as thermal energy in a high-temperature TES. This helps improve grid stability during periods of excess electricity production. During times of power-outage in the grid, the discharge of the TES is activated together with a novel SGS, which converts hot molten salt into high-pressure superheated steam. The steam drives a turbine and generates electricity to the grid through a Rankine Cycle. The exhaust steam is condensed into hot water and injected directly into the district heating network. The proposed solution is in perfect synergy with the continuous development of new wind farms, since they can assist in energizing the EB-TES-SGS system and help phase out the coal-fired boilers. During periods of cheap electricity, the EB can charge the TES system with electricity from the grid, typically in case of excess wind and/or PV. When the demand increases, and the price goes up, the TES is discharged and used to generate steam to drive the STG and feed electricity back into the grid. The integration to the DH network grants more flexibility, as the system can be optimized for both heat and power production.

Keywords: Power-to-X-to-Power, CPP, Retrofitting, TES, Smart Energy System, Hybrid System

Christian Thommessen is PhD student at the Chair of Energy Technology and works within a Graduation program for Sustainable Energy Systems in Neighborhoods by the Ministry of Culture and Science of the German state of North Rhine-Westphalia. His research deals with 100% renewable energy systems.

Techno-economic System Analysis of an Offshore Energy Hub and Outlook of Electrofuel Applications

Maximilian Otto, University of Duisburg-Essen; Christian Thommessen, University of Duisburg-Essen; Florian Nigbur, Lagom.Energy GmbH; Angelika Heinzel, The hydrogen and fuel cell center ZBT GmbH

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The integration of cross-sectoral energy hubs to large-scale wind farms opens up new applications for existing infrastructures and contributes to achieving renewable energy systems and climate protection targets. The offshore energy hub concept is to establish an artificially constructed energy conversion and distribution hub that addresses several energy-related markets: first, power supply to public grids and second, the possibility of converting renewable electricity into hydrogen or ammonia and supply it ashore. This enables smart integration of offshore wind power into gas grids. Furthermore, power generation from stored green gas on demand is able to cover residual power loads at low carbon intensity. However, an energy hub including electrofuel production provides an opportunity to export renewable fuels for sectors with traditional high greenhouse gas emissions, e.g. agriculture or transportation. Therefore, the concept has great decarbonization potentials, both economically and environmentally. In this contribution, an energy hub system in the North Sea is modeled and simulated with hourly weather data to determine production quantities and efficiencies of electricity, hydrogen and ammonia. The costs of several market options are calculated and compared. Results show that energy hubs can become sustainable pillars in future energy systems due to improving cost-competitiveness of wind power, but are expensive compared to today’s approaches based on fossil fuels.

Keywords: Ammonia, Electrofuels, Energy System Analysis, Hydrogen, Offshore Energy Hub, Power-to-Ammonia, Power-to-Gas, Sector Integration, Smart Energy Systems

As a PhD student, Kevin Verleysen continues the idea of his Master thesis by investigating the flexible production of green ammonia for energy transportation, storage and power generation applications.

Influence of parametric and operational uncertainties on the dynamic operation of the Haber-Bosch synthesis process for seasonal hydrogen storage

Kevin Verleysen, Vrije Universiteit Brussel ; Alessandro Parente, Université libre de Bruxelles ; Francesco Contino, UCLouvain

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In the energy transition, ammonia (NH3) can play a significant role in the storage of renewable energy as an energy carrier. The Haber-Bosch synthesis process enables the production of this energy carrier by combining nitrogen (N2) and electrolytic hydrogen (H2) under high temperature and pressure in the presence of a catalyst. To employ the Haber-Bosch process for its future role at a low cost, we require to investigate how the process could safely operate in a flexible and agile way and with a renewable power source. For pursuing this goal, a global sensitivity analysis on the dynamic Haber-Bosch process presents us with insight on which uncertainties have a major influence on the process. The current work involves the creation of a stochastic dynamic Haber-Bosch process and executing a global sensitivity analysis on the design under uncertainties. Within these uncertainties, we integrated operational (H2/N2 ratio) and parametric (reactor inlet temperature) uncertainties into the model to minimize the gap between real and simulated performance. The global sensitivity analysis showed the impact of the implemented uncertainties on the ammonia plant over time. The results show that the Haber-Bosch system can be used under suboptimal conditions when fluctuating the load of the plant, but the effect of uncertainties increases toward the nominal load. In future work, the feasibility of the Power-to-Ammonia concept can be validated by including more uncertainties in the model.

Keywords: Stochastic chemical systems, dynamic Haber-Bosch process, Power-to-Ammonia, uncertainty quantification

Louise Christensen graduated in 2018 from Aarhus University as MSc in Civil and Architectural Engineering, and worked 1,5 years as a consulting engineer. In 2019 she started a PhD study in the effect of occupant preferences and behaviors on model predictive control of residential space heating.

Thermal comfort and technology acceptance in homes with demand-responsive control of radiator thermostats

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Louise Christensen (presenter) lch@eng.au.dk

Economic model predictive control (E-MPC) of residential space heating shows potential to generate flexibility in district heating systems. This type of autonomous control utilizes indoor temperature fluctuations and thermal mass to shift energy need in time. However, investigations of occupant's acceptance of these temperature fluctuations and autonomous heating control systems are rare. This paper reports on a pilot study where digital radiator thermostats enabling remote control of heating set points were installed in six apartments in the same building in Denmark. During an intervention study, residents reported their perceived thermal comfort in the morning under three thermal conditions, and the study was supported by a semi-structured interview. Results showed that not all digital thermostats behaved as expected; the intervention only succeeded in three apartments. Some residents noticed the intervention, while others simply found the temperature 'comfortable'. None of the residents' thermal comfort was compromised by the intervention. Most residents were positive towards an autonomous digital heating system but stressed that some level of manual overrule was required. Overall, it is relevant to repeat the pilot study with more participants; however, developing a more robust plug-and-play autonomous thermostat solution is crucial.

Keywords: Thermal comfort, Smart heating, Load shifting, Field study, Survey

Yuriy Lobunets is a Leading research fellow at the Gas Institute of the National Academy of Sciences of Ukraine, an internationally renowned expert on thermoelectric energy conversion and renewable energy, member of International Thermoelectricity Academy and International Thermoelectric Society.

Regenerative Thermoelectric Heat Pump for HVAC Systems

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The proposed technology of the thermoelectric heat pump can drastically reduce the energy used for residential and commercial HVAC applications. The innovation is based on a new concept of the improvement of thermoelectric heat pumps, which simulates the ideal Lorentz cycle by dividing the total initial temperature range into a large number of small intervals, each of which runs by a micro heat pump (thermoelectric module) with high COP (up to COP>10). At the same time, the internal regeneration of heat between the spent and fresh heat carrier is provided. That will reduce energy use for cooling and heating a few-fold, thus potentially reducing primary energy consumption and greenhouse gas emissions. The scheme is able to meet the desirable 4-th Generation District Heating Systems characteristics:
• Part-load performance
• Flexible performance to provide grid services
• Net-zero water consumption
• Reduced size and weight relative to today’s high-efficiency units
• Readily available materials

Keywords: thermoelectric heat pump

Dmitry Romanov is a research associate whose field of interests includes energy saving and reducing temperatures in existing DH systems, feasibility study of different heat supply designs, hydraulic regimes of heat supply networks, coupling of heat and cold supply systems, and geothermal energy.

Technical, economic and ecological effects of lowering temperatures in the Moscow district heating system

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The energy-saving potential of Russian district heating systems is significant, and reducing the network temperatures can facilitate it. This work focuses on evaluating the technical, economic and ecological effects of the transition from the current 150/70 °C and 130/70 °C temperature charts to the 110/55 °C, 110/50 °C, 105/55 °C, 105/50 °C, 100/50 °C, and 95/50 °C temperature charts in the Moscow DH by means of a developed spreadsheet-based model. The reference case of 2016 and three cases with decreased heat demand in buildings by 5, 10, and 20 % were considered. The results show that heat losses in main pipelines can be reduced by 19-23 % with respect to current temperature charts. The 110/50 °C temperature chart is the most profitable option, with net present values varying from 0.85 to 6.55 bn RUB depending on the case. The 95/50 °C chart, which leads to a reduction of 349-443 (kt CO_2)/a, has the least impact on the environment. A more significant CO2 emissions reduction can be achieved by strong energy saving measures and broad utilization of renewable and waste energy. The essential prerequisite for the transition is a reduction of the heat demand in buildings by at least 20 %.

Keywords: Temperature charts, energy saving, heat losses, low temperature district heating, 4GDH, CO2 emissions reduction

Pierre JC Vogler-Finck has a background in energy engineering and control, with an industrial Ph.D. from Aalborg University in Denmark. He now works in R&D focusing on data-driven control and monitoring of building heating, aiming at improving its efficiency and integration within the energy systems.

Field experience of data-driven control and monitoring to support energy efficient and flexible building operation

Pierre JC Vogler-Finck, Neogrid Technologies ApS ; Per Dahlgaard Pedersen, Neogrid Technologies ApS ; Henrik Lund Stærmose, Neogrid Technologies ApS

Pierre JC Vogler-Finck (presenter) pvf@neogrid.dk

Energy efficiency and flexibility of the demand side are two essential enablers of the green transition. In Europe, the building sector uses about 40% of energy (with a majority to space and water heating) with a vastly untapped contribution potential on these two enabling levels.

Neogrid Technologies has been active in the Danish energy sector for a decade, mainly focusing on unlocking the potential of building heating systems to provide energy flexibility and efficiency by exploiting knowledge collected through online metering of energy demand and indoor climate from building management systems (BMS), IoT sensors and energy system operation.

Experience from data-driven control and fault detection with its cloud platform will be presented, illustrating possibilities offered by usage of data to improve building operations and usage of the technology in research and demonstration projects.

First, an application to reduction of energy demand and improvement of heat exchanger cooling in residential apartment blocks in district heating systems is provided. Then, examples of delivery of demand response in electricity and district heating systems are introduced. Lastly, the challenges of technology development and introduction of the solutions to the energy sector will be presented, illustrating some of the challenges faced on the demand side in the deployment of energy flexibility and efficiency to support a more integrated operation of the energy system.

Keywords: energy efficiency, energy flexibility, digitalisation, control technology, building heating operation, data, model-based control, smart-grid, technology

Benjamin Zühlsdorf is working as a consultant in commercial and publicly funded R&D projects at DTI. He holds a PhD about high performance heat pump systems and is involved as participant and project manager in various projects in the field of large-scale heat pumps for industry and district heating

Model-based fault detection for use in digital twins of large-scale heat pump systems

Benjamin Zühlsdorf, Danish Technological Institute, Wiebke Meesenburg; Technical University of Denmark; Brian Elmegaard, Technical University of Denmark

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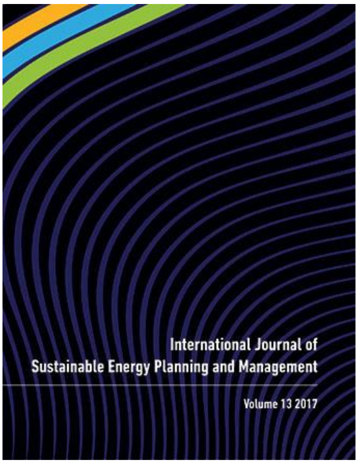
Large-scale heat pump systems are a key technology of sustainable future energy systems. Optimal performances and reliable operation are prerequisites for a wide deployment of such systems. In order to ensure optimal performances and identify fault mechanisms at an early stage, a continuous monitoring is inevitable. This paper presents a dynamic model for a large-scale ammonia heat pump system, which is able to continuously adapt to the current status of the physical system. The analytical model is developed in Dymola and may be automatically fitted to current measurements from an operating plant. It thereby enables the monitoring of drifting component efficiencies and indication of faulty behaviour. The developed procedure is demonstrated for a selected case study. The results indicated the adapting dynamic model to be a suitable basis for benchmarking system and component performances and for identifying component faults that are causing sub-optimal operating performances. Furthermore, the model enables a continuous set-point tuning as well as the derivation of optimal operating strategies with regard to non-productive periods, such has heat exchanger cleaning.

Keywords: Digital twin, District heating, Dynamic modelling, Fault detection, Set-point optimization

Special Issue Journals from previous SES Conferences

International Journal of Sustainable Energy Planning and Management, Vol 12 + 13 (2017)



Smart district heating and electrification
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Comparison of Low-temperature District Heating Concepts in a Long-Term Energy System Perspective
Rasmus Lund, Dorte Skaarup Østergaard, Xiaochen Yang, Brian Vad Mathiesen

Flexible use of electricity in heat-only district heating plants
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Innovative Delivery of Low Temperature District Heating System
Anton Ivanov Ianakiev

Techno-Economic Assessment of Active Latent Heat Thermal Energy Storage Systems with Low-Temperature District Heating
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Energy scheduling model to optimize transition routes towards 100% renewable urban districts
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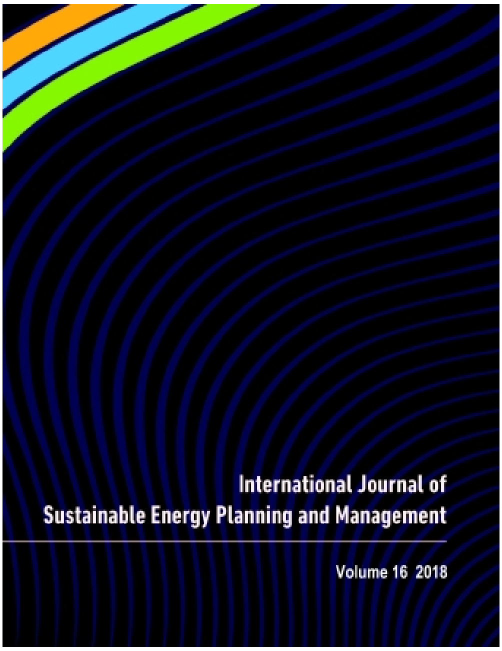
International Journal of Sustainable Energy Planning and Management, Vol 16 (2018)



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Economic incentives for flexible district heating in the Nordic countries
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Georg Konrad Schuchardt

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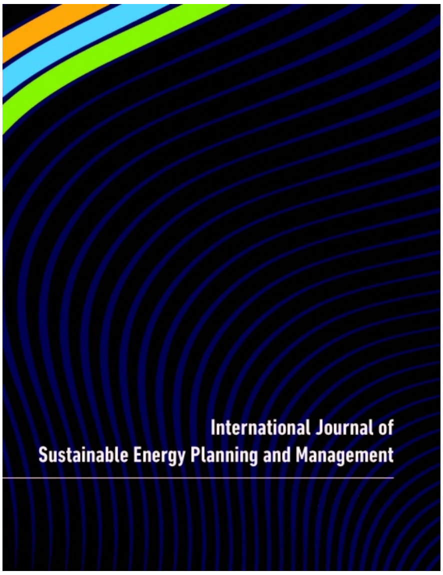

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A multi-objective optimization analysis to assess the potential economic and environmental benefits of distributed storage in district heating networks: a case study
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Modelling framework for integration of large-scale heat pumps in district heating using low-temperature heat sources
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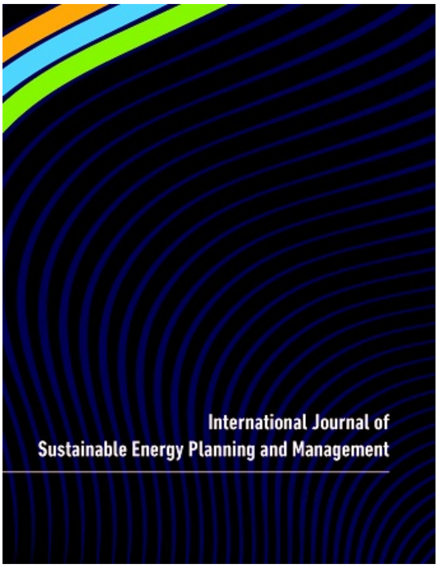

New Developments in 4th generation district heating and smart energy systems
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Planning of district heating regions in Estonia
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The role of 4th generation district heating (4GDH) in a highly electrified hydropower dominated energy system - The case of Norway
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EPLANopt optimization model based on EnergyPLAN applied at regional level: the future competition on excess electricity production from renewables
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A novel method for forecasting electricity prices in a system with variable renewables and grid storage
Salman Siddiqui, John Macadam, Mark Barrett

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Special issue on Smart Energy Systems and 4th Generation District Heating
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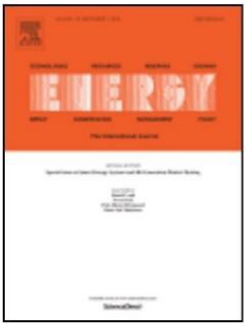

Smart energy systems and 4th generation district heating
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Hydrogen to link heat and electricity in the transition towards future Smart Energy Systems
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A methodology for designing flexible multi-generation systems
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Case study of the constraints and potential contributions regarding wind curtailment in Northeast China
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Replacing critical radiators to increase the potential to use low-temperature district heating – A case study of 4 Danish single-family houses from the 1930s
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System dynamics model analysis of pathway to 4th generation district heating in Latvia
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Low temperature district heating in Austria: Energetic, ecologic and economic comparison of four case studies
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Complex thermal energy conversion systems for efficient use of locally available biomass
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Current and future prospects for heat recovery from waste in European district heating systems: A literature and data review
Urban Persson, Marie Münster

Mapping of potential heat sources for heat pumps for district heating in Denmark
Rasmus Lund, Urban Persson

Industrial surplus heat transportation for use in district heating
J.NW. Chiu, J. Castro Flores, V. Martin, B. Lacarrière

European space cooling demands
Sven Werner

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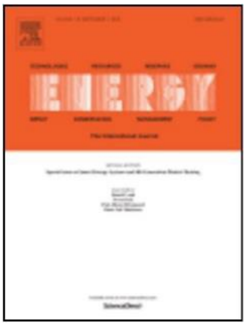

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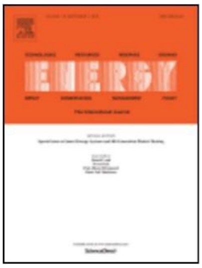

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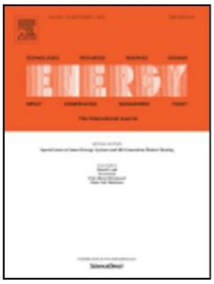

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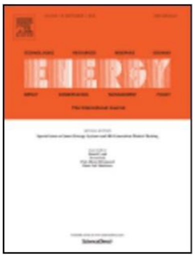

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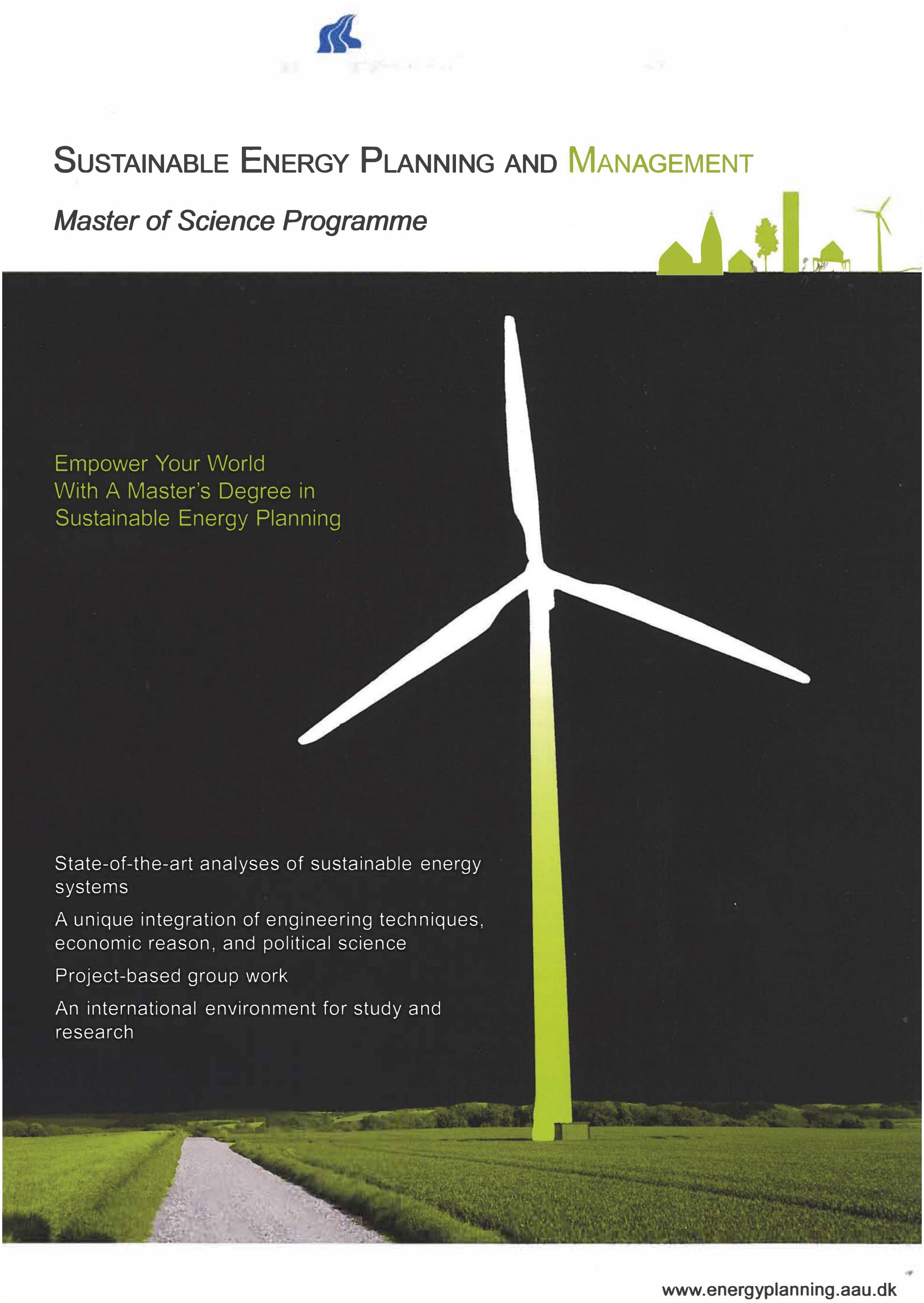

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