Book of Abstracts

8th International Conference on Smart Energy Systems

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8TH INTERNATIONAL CONFERENCE ON SMART ENERGY SYSTEMS

Aalborg, 13-14 September 2022

BOOK OF ABSTRACTS

energy CLUSTER DENMARK

AALBORG UNIVERSITY
DENMARK

8th International Conference on Smart Energy Systems
13-14 September 2022

Book of Abstracts

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Department of Planning
Rendsburggade 14
9000 Aalborg

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Preface

It is a great pleasure to welcome you to the **8th International Conference on Smart Energy Systems** on 13-14 September 2022. The conference is organised by Aalborg University and Energy Cluster Denmark. We thank the sponsors for their contribution to this year's conference: EMD International, Kamstrup, Kingspan, Danfoss, Grundfos, Grøn Energi, Innargi and Ørsted.

Again in 2022, we look forward to welcoming our participants to a hybrid conference with both online and in-person participation from academia and industry around the world. In Aalborg, you can attend the conference sessions in person, while the online conference platform enables you to watch all recorded presentations; interact in writing with the presenters and nominate candidates for the Best Presentation Award. The online conference platform will be open both before and after the conference in Aalborg.

In the past two years, the COVID 19 pandemic made an impact on the conference – however, only resulting in minor setbacks regarding the deployment of renewable energy and energy efficient technologies. The backdrop of this year's conference is the Russian unprovoked attack on Ukraine. The series of events since the initial attack on 24 February 2022 has underlined that energy security must be a pivotal part of energy policy. A reliance on Russia for natural gas, oil, coal, and biomass supplies has demonstrated serious flaws in European energy policies, and the events unfolding have renewed a focus on self-reliance – amongst others, on locally deployed renewable energy technologies.

The International Conference on Smart Energy Systems 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.

The 8th 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 23 countries around the world – to a programme with seven strong keynote profiles and 125 session presentations as well as technical tours. All presentations, discussions, talks and debates during the conferences contribute to the understanding and development of future energy systems. We thank everyone for your valuable contributions.

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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FOR ABSTRACTS

8th International Conference on

Smart Energy Systems

4th Generation District Heating, Electrification, Electrofuels and Energy Efficiency

13-14 September 2022, Aalborg

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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 2022

28 March	**Deadline submission of abstracts** (Additional upgrade to paper is optional)
08 April	**Reply on acceptance of abstracts**
25 April - 24 May	**Early registration**
25 May - 05 Aug	**Normal registration**
13 - 14 Sept	**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

Conference fees

- Early registration (for presenters with accepted abstracts):
  350 EUR (attendance in Aalborg) / **250 EUR** (virtual attendance)
- Normal fee: **450 EUR** (attendance in Aalborg) / **350 EUR** (virtual attendance)
- Additional fee for conference dinner (Aalborg): **100 EUR**

4DH

reINVEST

Innovation Fund Denmark

sEEnergies

Funded by the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement no. 846463

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, electrofuels and energy efficiency. This 8th 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 Energy Cluster Denmark.

Format

Again in 2022, we look forward to welcoming our participants to a hybrid conference with the possibility to attend either online or in person – this time in Aalborg. In Aalborg, you can attend the conference sessions in person, while the online conference platform enables you to attend the conference virtually. Via the platform you will have access to watch all recorded presentations; interact in writing with the presenters and nominate candidates for the Best Presentation Award. The online conference platform will be open both before and after the conference in Aalborg.

Conference Chairs

Prof. Henrik Lund, Aalborg University
Prof. Brian Vad Mathiesen, Aalborg University
Prof. Poul Alberg Østergaard, Aalborg University
Hans Jørgen Brodersen, Senior Project Manager, Energy Cluster Denmark

Submission Procedure

Both scientific and industrial contributions to the conference are most welcome.

To attend the conference as a presenter, you need to submit both an **abstract** and a **recorded presentation**. The abstract must be submitted by 28 March 2022. The recorded presentation must be prepared in the summer of 2022. Once your abstract is accepted for presentation, you will receive more information and a guideline to the recording of your presentation. Abstracts can be submitted via **www.smartenergysystems.eu** from **15 December 2021 to 28 March 2022.**

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

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

International Scientific Committee

Prof. Anton Ianakiev, Nottingham Trent University, GB
Prof. Bent Ole G. Mortensen, University of Southern Denmark
Prof. Bernd Möller, University of Flensburg, DE
Prof. Christian Breyer, Lappeeranta University of Tech, FI
Prof. Dagnija Blumberga, Riga Technical University, LV
Prof. Erik Ahlgren, Chalmers University of Technology, SE
Prof. Ernst Worrell, Utrecht University, NL
Prof. Ingo Weidlich, HafenCity University, DE
Prof. Leif Gustavsson, Linnaeus University, SE
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Gareth Jones, Managing Director at Fairheat, GB
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8th International Conference on

Smart Energy Systems

4th Generation District Heating, Electrification, Electrofuels and Energy Efficiency

ONLINE PROGRAMME - KEYNOTE SESSIONS
ACCESSIBLE FROM 14 SEPTEMBER

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AALBORG UNIVERSITY

Sector integration in urban areas - 1st plenary session chaired by Associate Professor Iva Ridjan Skov

Professor Henrik Lund and CEO Glenda Napier: Opening speech

Plenary keynotes:

Jesper Møller Larsen, Manager of District Energy Systems: Using the right energy, right in Aalborg – taking the common energy solutions to the next (green) level

David Dupont-Mouritzen, Project Director: Power-to-X as a key for the green transition

Samir Abboud, CEO: Industrializing geothermal energy for urban district heating

Professor Sven Werner: The four generations of district cooling - a categorization of the development in district cooling from origin to future prospect

European energy security and the war in Ukraine - 2nd plenary session chaired by Professor Poul Alberg Østergaard

Plenary keynotes:

Professor Brian Vad Mathiesen: Energy Efficiency First - REPower EU 2030 and 100% renewable energy in 2050 for Europe

Connie Hedegaard, former EU Commissioner and Minister: We know both the Danish targets and the EU's Fit for 55. But are our systems fit for implementation?

Prof. Dr. Andreas Löschel: After the "Zeitenwende" (turn of the times) is before the test - The path to climate neutrality between the Ukraine war and the coal phase-out

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Closing by Professor Henrik Lund

Smart energy systems analyses, tools and methodologies

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Casey Cole: Digitalising heat network commissioning - using apps to bridge the skills gap

Rémi Delage: Cluster analysis of Japanese households based on energy consumption mix

Hermann Edtmayer: Analysing the thermal energy demand of development scenarios of a city district

ASM Mominul Hasan: Virtual net-metering and citizen investment for boosting energy transition in the cities of emerging economies: A case study on Bangladesh

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Henrik Håkansson: Model predictive control for heating systems when using demand tariffs

Salman Javed: Demand Response in Distributed Energy Systems of Systems Using Local-Cloud: An Approach towards Net-Zero Emissions

Joseph Jebamalai: Design of district heating networks using a ring network and storage configuration – A case study using Comsof Heat

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Aadit Malla: Validation approaches under GDPR constraints for bottom-up building stock energy data: Case Vienna

Philipp Mascherbauer: Validation of modeling smart energy management systems in reduced order models with building simulation models

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Peter Nageler: IDA Districts: a QGIS plugin for automated thermal model generation and dynamic district simulation

Martin Neumayer: Fault and anomaly detection in district heating substations: A survey focused on methodology and data sets

Matteo Giacomo Prina: Evaluating near-optimal scenarios with EnergyPLAN to support policy makers

Michael Reisenbichler: Novel modeling toolkit for optimized design and integration of large-scale underground hot-water thermal energy storages in future energy systems

Akos Revesz: Heat decarbonisation opportunities in urban neighborhoods – Building retrofit and low carbon energy supply assessment

Maximilian Roth: Optimal component dimensioning and operational optimization of a mobile-hybrid energy supply system with defined system topology using MILP

Shivangi Sachar: Wind energy potential assessment for the city of Nottingham using Weibull distribution estimation

Robbe Salenbien: Showcasing the potential of non-linear topology optimization of District Heating Networks – District level and upwards

Malte Schäfer: Life cycle oriented decision support for companies to reduce electricity-related greenhouse emissions

Shubham Shubham: Feasibility study of different vertical axis wind turbines for wind conditions in the city of Nottingham

Peter Sorknæs: The benefits of 4th generation district heating and energy efficient datacentres

Jan Stock: Modelling of an Existing District Heating Network at Different Supply Temperatures with a New Integrated Waste Heat Source

Henrik Stærmose: Flexibility Heat Grid Bornholm

Jakob Zinck Thellufsen: From energy modelling to energy planning – the consequence of different types of system analysis

Anna Vannahme: Central and decentral operation strategies to optimize existing district heating networks

Anna Vocke: The impact of increased information content on electricity load forecasting

Yannick Wack: Approaches to non-linear topology optimization of District Heating Networks – A benchmark

Daniel Zinsmeister: A prosumer-based sector-coupled district heating and cooling laboratory architecture

Smart energy infrastructure and storage options

Kamil Kwiatkowski: Heat pumps with triple heat storage levels for district heating system with 90 % of energy from renewable sources – a feasibility study with TRNSYS

Richard van Leeuwen: Business case scenario analysis for hydrogen conversion, storage and consumption within energy hubs

Mattia Pasqui: Renewable Energy Communities: techno-economic assessment focusing on heat pump load shifting

Thomas Riegler: Structural challenges and innovative concepts for large-scale underground thermal energy storage

Vittorio Verda: Efficient Heat Pump integration in existing large district heating networks

Thilo Walser: Technical and economical optimisation of district heating networks with decentralised buffer storage tanks

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Leif Gustavsson: A sustainable replacement for diesel trucking: Comparing battery electric and biofuel trucks

Rasmus Lund: Is storage needed in sector coupling?

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Hironao Matsubara: Control and utilization of surplus electricity for the high share of variable renewable energy in Japan

Benedetto Nastasi: Power To Hydrogen for Energy Flexible Communities

Hiroaki Onodera: Renewable Energy Systems Considering Profitability of PtG and PtL - a Case Study of Japan

Matteo Pozzi: Integrated Planning of Multi-Energy Systems (PlaMES): the Decision Support System and exploitation opportunities

Els van der Roest: Heat utilization from hydrogen production – an example of local energy system integration

Costanza Saletti: Implementation and testing of a multi-level smart control strategy for the integrated energy system of a hospital

Christian Schützenhofer: IEA DHC Annex TS7: Industry-DHC Symbiosis: A systemic approach for highly integrated industrial and thermal energy systems

Yudha Irmansyah Siregar: Assessment of transport electrification and district cooling towards smart energy systems in hot climate countries

Iva Ridjan Skov: Fast forward for power-to-x in Denmark: the role of advocacy coalitions in shaping policy

Marie-Alix Dupré la Tour: Aggregation of heat networks for their integration in European scale sector-coupling studies

Øyvind Vessia: Unlocking grid savings through PtX when integrating offshore wind energy

Andreas Weiß: Assessment of Resulting Loads and Constraints Applying Clustering Approaches for Determination of Representative Distribution Grids

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

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Martijn Clarijs: WarmingUP Design Toolkit for Future-proof Heat Networks

Mostafa Fallahnejad: Overview of district heating potentials in EU-27 countries under evolving DH market shares and ambitious heat demand reduction scenario

Patxi Hernandez: City zoning for heating and cooling : Methodology for prioritization of solutions at building or district scale

Ivan Munoz: Determination of the technical-economic potential for the development of district heating projects in each commune of Chile

Bernd Möller: Synergies between geographically distributed energy efficiency potentials

Somadutta Sahoo: Detailed energy system modeling of a district heating network on a provincial level – a study of Groningen Province in the northern Netherlands

8th International Conference on

Smart Energy Systems

4th Generation District Heating, Electrification, Electrofuels and Energy Efficiency

ONLINE PROGRAMME

SESSIONS OPEN FROM 9 TO 16 SEPTEMBER 2022

Planning and organisational challenges for smart energy systems and district heating

Vita Brakovska: Gamification in System Dynamic Modelling Simulation Tools Used to Support Transition Towards a Carbon-Neutral Energy Communities

Richard Büchele: Economic and ecological feasibility of district heating in a deeply renovated housing estate

Daniel Heidenthaler: Automated urban building energy modelling approach for predicting heat load profiles of districts

Igor Krupenski: Converting the heating system of the historic center of Tallinn (Old Town) to a district heating system

Ari Laitala: Calculating existing buildings carbon footprint based on open data – role of the energy

Poul Thøis Madsen: The employment impact of smart energy systems in EU as a whole - a review of previous studies

Graeme Maidment: The generation gap! Are we using the correct terminologies in the sector?

Yannis Merlet: Retrofitting second-generation district heating networks towards lower temperatures with optimal design tools

Jason Runge: A comparison of prediction and forecasting artificial intelligence models to estimate the future energy demand in a district heating system

Anna Volkova: Estonian Energy Roadmap to Carbon Neutrality

Yong Yang: Expanding district heating to southern China: Current status and future trend towards 2060

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Kristina Lygnerud: Metro waste heat recovery - lessons from London and Berlin

Marco Cozzini: Analysis of low-temperature waste heat recovery scenarios for a case study in a conventional district heating network

Sebastian Schultze: District Energy in 2050 – Business models and sustainable finance solutions

Felix Reinhardt/Karl Sperling: Developing District-Level Energy Concepts In Aalborg (Denmark) And Wittenberge (Germany) Discussion of Heat Planning vs. District-Level Energy Concept

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

Marek Brand: Decentralized district heating stations in newly built multi-apartment buildings - documenting the performance and low return temperature

Marcus Hummel: Costs and potentials for heat savings in existing buildings in Europe

Kevin Naik: Zero energy rating of residential homes leveraging wind and solar energy

Simon Thorsteinsson: Experimental energy flexibility study of space heating of a BR2020 one-family house with heat pump, floor heating and photovoltaics

Ruta Vanaga: On-site Testing of Dynamic Facade System with the Solar Energy Storage

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

Antoine Fabre: Cost benefit analysis of retrofit actions on the building secondary hydronic systems on the district heating

Elisa Guelpa: Reducing supply temperature in existing large scale district heating

Nicola Cesare Di Nunzio: Reducing temperature of existing building heating systems: a simplified modeling approach

Thibaut Wissocq: Generation of simulated faulty datasets to ease Heating Network fault detection using machine learning

Special Session: Heat 4.0

Alfred Heller: Cross System Optimisation – A HEAT 4.0 Tool

Per Sieverts Nielsen: Experiences from the Danish Innovation project – HEAT 4.0

Alex Arash Sand Alsing Kalaee: Field experience of data-driven operation of building heating to unlock energy efficiency

Jan Eric Thorsen: Adaptive control strategy for domestic hot water storage tank supplied by district heating

Kevin Michael Smith: A novel controller using minimal district heating flows to charge domestic hot water tanks

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ONLINE PROGRAMME

SESSIONS OPEN FROM 9 TO 16 SEPTEMBER 2022

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

Larissa Beierlein: Holistic comparison on existing guidelines for the development of heat transformation guidelines

Martin Crane: Scope for hybrid PV to improve GSHP CoPs and reduce ground loop size

Kristian Gjoka: Fifth generation district heating and cooling: opportunities and implementation challenges in a mild climate

Oddgeir Gudmundsson: Cooling as an integrated part of 4th generation district heating

Ana Catarina Marques: Driving success towards zero carbon energy targets for UK's Local Authorities

Bernhard Mayr: Evaluation of Gas Demand in Space Heating and Hot Water Preparation at NUTS 3 Level regarding the Dependence on Russian Natural Gas

Ali Moallemi: Xplorion: An Innovative Sustainable Building Supplied by Low and Ultra-Low Temperature District Heating System

Ieva Pakere: Multi-source district heating system optimisation trough technical, economic and life-cycle analyses

Flemming Bligaard Pedersen: Cost-effective Solar Powerplant delivering flexible electricity and district heating on demand

Hannes Poier: Demonstration of large scale solar district heating integration with storages and biomass - synergies and challenges

Luis Sánchez-García: Viability of district heating networks in temperate climates: Benefits and barriers of ultra-low cold and warm temperature networks

Uffe Schleiss: How to effectively convert gas area into district heating

Daniel Møller Sneum: Switching from natural gas to district heating: Measured impacts on household energy use

Jelena Ziemele: Impacts of global warming and building renovation on the heating energy demand and district heating capacity: Case of the city of Riga

Renewable energy sources and waste heat sources for district heating

Dagnija Blumberga: Harmonisation of waste heat in district heating

Ali Kök: The distance between industrial sites and district heating grids as a driver of the economic viability of waste heat integration

Henrique Lagoeiro: Heat Recovery Opportunities from Electrical Substations

Kertu Lepiksaar: Utilisation of Sewage Water Heat in District Heating and the Impact on the Water Treatment Process

Ingo Leusbrock: How to combine district heating and waste water treatment plants? A demonstration example from Gleisdorf, Austria

Nicolas Marx: Decarbonizing the heating supply via regional district heating networks – Best Practice Analysis and Status-Quo for a case study in Tyrol (Austria)

Johannes Pelda: Identifying locations for optimal heat extraction from city waste water

Stefan Reuter: Techno-economic assessment of waste heat utilization: Design and implementation of a rapid assessment tool

Dmitry Romanov: Analysis of Enhanced Geothermal System Development Scenarios for District Heating and Cooling of the Göttingen University Campus

Abdulraheem Salaymeh: Analysis to determine the potential of waste water heat to supply urban areas

Giulia Spirito: An industrial waste heat recovery atlas: identification of recovery coefficients and parametrization of storage size according to different DH demand

Special Session: IEA DHC Annex TS4 and IEA EBC Annex 84

Dietrich Schmidt: Digitalisation in district heating supply – with data to optimised systems and new business opportunities

Michele Tunzi: Digitalization of Demand side as the enabler for the transition towards 4th Generation district heating (4GDH)

Pakdad Pourbozorgi Langroudi: A Combi-Model for Failure Prediction of the Pre-Insulated Pipes in District Heating/Cooling Networks

Jakob Fester: Algorithms for assessing the condition of district heating service pipes exploiting GIS data, data from smart meters and soil temperature measurements

Ralf-Roman Schmidt: The AIT DigitalEnergyTestbed: An open test environment for digitalization solutions for integrated district heating networks

Anna Marszal-Pomianowska: IEA EBC Annex 84: Demand Management of Buildings in Thermal Networks

Anna Kallert: IEA EBC Annex 84: Demand Management of Buildings in Thermal Networks – Case Studies including DH and DC Systems

Tijs Van Oevelen: Testing a smart controller for district heating systems : Results from an Italian case study in the TEMPO project

Konstantin Filonenko: Evaluation of district heating operation using flexibility function and Functional Mockup Interface

Technical Tour: Broenderslev utilities tour

Monday 12 September 2022
14:00-17:00

We go on a bus trip to Broenderslev, where you can see how the power of the sun even so far north can add to the green transition. Broenderslev municipality north of Aalborg has among other initiatives the aim to become fossil free for their district heating. Here you can visit a state-of-the-art energy plant that uses local wood chips and concentrated solar power to supply district heating and electricity to the town of Brønderslev with a population of 12,000 people. The energy plant has been expanded with 5 km of CSP solar collectors and together with two chip boilers supply the energy to an ORC turbine. Furthermore, the plant's electricity needs are partly covered by introducing concentrated solar power in their heat production.

More information at conference website

8th International Conference on

Smart Energy Systems

4th Generation District Heating, Electrification, Electrofuels and Energy Efficiency

PROGRAMME AALBORG

TUESDAY 13 SEPTEMBER 2022

08:00-09:00 **Registration and breakfast** **Foyer**

09:00-11:00 **Sector integration in urban areas** - 1st plenary session chaired by Associate Professor Iva Ridjan Skov **Europahallen**

09:00-09:15 **Professor Henrik Lund and CEO Glenda Napier:** Opening speech

Plenary keynotes:

09:15-09:30 **Jesper Møller Larsen, Manager of District Energy Systems:** Using the right energy, right in Aalborg – taking the common energy solutions to the next (green) level

09:30-09:45 **David Dupont-Mouritzen, Project Director:** Power-to-X as a key for the green transition

09:45-10:00 **Samir Abboud, CEO:** Industrializing geothermal energy for urban district heating

10:00-10:30 Questions and debate

10:30-11:00 **Professor Sven Werner:** The four generations of district cooling - a categorization of the development in district cooling from origin to future prospect

11:00-11:15 **Short break**

Parallel sessions 1-5

11:15-12:45 **Room: Musiksalen**

Session 1: 4th Generation District Heating concepts, future district heating production and systems

Chair: Robin Wiltshire

Session keynote Oddgeir Gudmundsson: Cooling as an integrated part of 4th generation district heating

Luis Sánchez-García: Viability of district heating networks in temperate climates: Benefits and barriers of ultra-low cold and warm temperature networks

Kristian Gjoka: Fifth generation district heating and cooling: opportunities and implementation challenges in a mild climate

Larissa Beierlein: Holistic comparison on existing guidelines for the development of heat transformation guidelines

11:15-12:45 **Room: Gæstesalen**

Session 2: Integrated Energy Systems and Smart Grids

Chair: Steen Schelle Jensen

Session keynote Øyvind Vessia: Unlocking grid savings through PtX when integrating offshore wind energy

Benedetto Nastasi: Power To Hydrogen for Energy Flexible Communities

Iva Ridjan Skov: Fast forward for power-to-x in Denmark: the role of advocacy coalitions in shaping policy

Tansu Galimova: Impact of international transportation options on cost of green e-hydrogen supply: Global cost of hydrogen and consequences for Germany and Finland

Els van der Roest: Heat utilization from hydrogen production – an example of local energy system integration

11:15-12:45 **Room: Laugsstuen**

Session 3: Smart energy systems analyses, tools and methodologies

Chair: Gareth Jones

Session keynote Hermann Edtmayer: Analysing the thermal energy demand of development scenarios of a city district

Henrik Håkansson: Model predictive control for heating systems when using demand tariffs

Salman Javed: Demand Response in Distributed Energy Systems of Systems Using Local-Cloud: An Approach towards Net-Zero Emissions

Maximilian Roth: Optimal component dimensioning and operational optimization of a mobile-hybrid energy supply system with defined system topology using MILP

Rémi Delage: Cluster analysis of Japanese households based on energy consumption mix

11:15-12:45 **Room: Latinerstuen**

Session 4: Smart energy systems analyses, tools and methodologies

Chair: Dietrich Schmidt

Session keynote Casey Cole: Digitalising heat network commissioning - using apps to bridge the skills gap

Matteo Giacomo Prina: Evaluating near-optimal scenarios with EnergyPLAN to support policy makers

Jakob Zinck Thellufsen: From energy modelling to energy planning – the consequence of different types of system analysis

Jan Stock: Modelling of an Existing District Heating Network at Different Supply Temperatures with a New Integrated Waste Heat Source

Michael Reisenbichler: Novel modeling toolkit for optimized design and integration of large-scale underground hot-water thermal energy storages in future energy systems

11:15-12:45 **Room: Bondestuen**

Special session: Heat 4.0

Chair: Kevin Michael Smith

Session keynote Alfred Heller: Cross System Optimisation – A HEAT 4.0 Tool

Per Sieverts Nielsen: Experiences from the Danish Innovation project – HEAT 4.0

Alex Arash Sand Alsing Kalaee: Field experience of data-driven operation of building heating to unlock energy efficiency

Jan Eric Thorsen: Adaptive control strategy for domestic hot water storage tank supplied by district heating

Kevin Michael Smith: A novel controller using minimal district heating flows to charge domestic hot water tanks

8th International Conference on

Smart Energy Systems

4th Generation District Heating, Electrification, Electrofuels and Energy Efficiency

PROGRAMME AALBORG

TUESDAY 13 SEPTEMBER 2022

12:45-14:00 Lunch and networking — **Restaurant**

Parallel sessions 6-10

14:00-15:45 Room: Musiksalen

Session 6: Geographical Information Systems (GIS) for energy systems, heat planning and district heating

Chair: Urban Persson

Session keynote Bernd Möller: Synergies between geographically distributed energy efficiency potentials

Mostafa Fallahnejad: Overview of district heating potentials in EU-27 countries under evolving DH market shares and ambitious heat demand reduction scenario

Patxi Hernandez: City zoning for heating and cooling : Methodology for prioritization of solutions at building or district scale

Somadutta Sahoo: Detailed energy system modeling of a district heating network on a provincial level – a study of Groningen Province in the northern Netherlands

Martijn Clarijs: WarmingUP Design Toolkit for Future-proof Heat Networks

Ivan Munoz: Determination of the technical-economic potential for the development of district heating projects in each commune of Chile

14:00-15:45 Room: Gæstesalen

Session 7: Renewable energy sources and waste heat sources for district heating

Chair: Dagnija Blumberga

Session keynote Ingo Leusbrock: How to combine district heating and waste water treatment plants? A demonstration example from Gleisdorf, Austria

Johannes Pelda: Identifying locations for optimal heat extraction from city waste water

Kertu Lepiksaar: Utilisation of Sewage Water Heat in District Heating and the Impact on the Water Treatment Process

Nicolas Marx: Decarbonizing the heating supply via regional district heating networks – Best Practice Analysis and Status-Quo for a case study in Tyrol (Austria)

Stefan Reuter: Techno-economic assessment of waste heat utilization: Design and implementation of a rapid assessment tool

Dmitry Romanov: Analysis of Enhanced Geothermal System Development Scenarios for District Heating and Cooling of the Göttingen University Campus

14:00-15:45 Room: Laugsstuen

Session 8: Smart energy infrastructure and storage options

Chair: Benedetto Nastasi

Session keynote Richard van Leeuwen: Business case scenario analysis for hydrogen conversion, storage and consumption within energy hubs

Thomas Riegler: Structural challenges and innovative concepts for large-scale underground thermal energy storage

Thilo Walser: Technical and economical optimisation of district heating networks with decentralised buffer storage tanks

Kamil Kwiatkowski: Heat pumps with triple heat storage levels for district heating system with 90 % of energy from renewable sources – a feasibility study with TRNSYS

Mattia Pasqui: Renewable Energy Communities: techno-economic assessment focusing on heat pump load shifting

Vittorio Verda: Efficient Heat Pump integration in existing large district heating networks

14:00-15:45 Room: Latinerstuen

Session 9: Smart energy systems analyses, tools and methodologies

Chair: Matteo Giacomo Prina

Session keynote Peter Sorknæs: The benefits of 4th generation district heating and energy efficient datacentres

Gideon Mbiydzenyuy: Toward the application of Data Analytics for Fault Detection in District Heating Substations

ASM Mominul Hasan: Virtual net-metering and citizen investment for boosting energy transition in the cities of emerging economies: A case study on Bangladesh

Robbe Salenbien: Showcasing the potential of non-linear topology optimization of District Heating Networks – District level and upwards

Yannick Wack: Approaches to non-linear topology optimization of District Heating Networks – A benchmark

Anna Vannahme: Central and decentral operation strategies to optimize existing district heating networks

14:00-15:45 Room: Bondestuen

Session 10: Integrated energy systems and smart grids

Chair: Leif Gustavsson

Session keynote Costanza Saletti: Implementation and testing of a multi-level smart control strategy for the integrated energy system of a hospital

Hironao Matsubara: Control and utilization of surplus electricity for the high share of variable renewable energy in Japan

Christian Schützenhofer: IEA DHC Annex TS7: Industry-DHC Symbiosis: A systemic approach for highly integrated industrial and thermal energy systems

Marie-Alix Dupré la Tour: Aggregation of heat networks for their integration in European scale sector-coupling studies

Matteo Pozzi: Integrated Planning of Multi-Energy Systems (PlaMES): the Decision Support System and exploitation opportunities

Rasmus Lund: Is storage needed in sector coupling?

15:45-16:15 Coffee break

8th International Conference on

Smart Energy Systems

4th Generation District Heating, Electrification, Electrofuels and Energy Efficiency

PROGRAMME AALBORG

TUESDAY 13 SEPTEMBER 2022

Parallel sessions 11-15

16:15-17:30 Room: Musiksalen

Session 11: Components and systems for district heating, energy efficiency, electrification and electrofuels

Chair: Poul Thøis Madsen

Session keynote: Session keynote Elisa Guelpa: Reducing supply temperature in existing large scale district heating

Antoine Fabre: Cost benefit analysis of retrofit actions on the building secondary hydronic systems on the district heating

Nicola Cesare Di Nunzio: Reducing temperature of existing building heating systems: a simplified modeling approach

Thibaut Wissocq: Generation of simulated faulty datasets to ease Heating Network fault detection using machine learning

16:15-17:30 Room: Gæstesalen

Session 12: Renewable energy sources and waste heat sources for district heating

Chair: Richard van Leeuwen

Session keynote Dagnija Blumberga: Harmonisation of waste heat in district heating

Ali Kök: The distance between industrial sites and district heating grids as a driver of the economic viability of waste heat integration

Henrique Lagoeiro: Heat Recovery Opportunities from Electrical Substations

Giulia Spirito: An industrial waste heat recovery atlas: identification of recovery coefficients and parametrization of storage size according to different DH demand

16:15-17:30 Room: Laugsstuen

Session 13: Planning and organisational challenges for smart energy systems and district heating

Chair: Bernd Möller

Session keynote Richard Büchele: Economic and ecological feasibility of district heating in a deeply renovated housing estate

Ari Laitala: Calculating existing buildings carbon footprint based on open data – role of the energy

Daniel Heidenthaler: Automated urban building energy modelling approach for predicting heat load profiles of districts

Jason Runge: A comparison of prediction and forecasting artificial intelligence models to estimate the future energy demand in a district heating system

16:15-17:30 Room: Latinerstuen

Session 14: 4th Generation District Heating concepts, future district heating production and systems

Chair: Peter Jorsal

Session keynote Uffe Schleiss: How to effectively convert gas area into district heating

Daniel Møller Sneum: Switching from natural gas to district heating: Measured impacts on household energy use

Jelena Ziemele: Impacts of global warming and building renovation on the heating energy demand and district heating capacity: Case of the city of Riga

16:15-17:30 Room: Bondestuen

RewardHeat Special Session: Technologies and management strategies of low- and neutral-temperature district heating and cooling grids

Chair: Karl Sperling

Session keynote Kristina Lygnerud: Metro waste heat recovery - lessons from London and Berlin

Marco Cozzini: Analysis of low-temperature waste heat recovery scenarios for a case study in a conventional district heating network

Sebastian Schultze: District Energy in 2050 – Business models and sustainable finance solutions

Karl Sperling: Developing District-Level Energy Concepts In Aalborg (Denmark) And Wittenberge (Germany) Discussion of Heat Planning vs. District-Level Energy Concept

17:30-19:30 Break

19:30 Conference dinner at Hotel Comwell Hvide Hus, Vesterbro 2, 9000 Aalborg

8th International Conference on

Smart Energy Systems

4th Generation District Heating, Electrification, Electrofuels and Energy Efficiency

PROGRAMME AALBORG

WEDNESDAY 14 SEPTEMBER 2022

Parallel sessions 16-20

09:00-10:30 Room: Musiksalen

Session 16: Energy savings in the electricity sector, buildings, transport and industry

Chair: Jan Eric Thorsen

Session keynote Marek Brand: Decentralized district heating stations in newly built multi-apartment buildings - documenting the performance and low return temperature

Kevin Naik: Zero energy rating of residential homes leveraging wind and solar energy

Marcus Hummel: Costs and potentials for heat savings in existing buildings in Europe

Simon Thorsteinsson: Experimental energy flexibility study of space heating of a BR2020 one-family house with heat pump, floor heating and photovoltaics

Ruta Vanaga: On-site Testing of Dynamic Facade System with the Solar Energy Storage

09:00-10:30 Room: Gæstesalen

Session 17: Smart energy systems analyses, tools and methodologies

Chair: Dirk Vanhoudt

Session keynote Andra Blumberga: The Profile of a "Hard-to-Reach" Energy Consumers of the Baltic and Nordic States in the Process of Energy Transition

Daniel Zinsmeister: A prosumer-based sector-coupled district heating and cooling laboratory architecture

Henrik Stærmose: Flexibility Heat Grid Bornholm

Aadit Malla: Validation approaches under GDPR constraints for bottom-up building stock energy data: Case Vienna

Thomas Licklederer: A field-level control approach for bidirectional heat transfer stations in prosumer-based thermal networks: simulation and experimental evaluation

09:00-10:30 Room: Laugsstuen

Session 18: Smart energy systems analyses, tools and methodologies

Chair: Stefan Holler

Session keynote Akos Revesz: Heat decarbonisation opportunities in urban neighborhoods – Building retrofit and low carbon energy supply assessment

Joseph Jebamalai: Design of district heating networks using a ring network and storage configuration – A case study using Comsof Heat

Philipp Mascherbauer: Validation of modeling smart energy management systems in reduced order models with building simulation models

Thomas Haupt: Analyzing the impact of Smart Energy Management Systems on the economy of various PV and battery systems for individual households

Rasmus Magni Johannsen: Municipal energy system modelling – a practical comparison of optimisation and simulation approaches

09:00-10:30 Room: Latinerstuen

Session 19: Planning and organisation challenges for smart energy systems and district heating

Chair: Steffen Nielsen

Session keynote Anna Volkova: Estonian Energy Roadmap to Carbon Neutrality

Poul Thøis Madsen: The employment impact of smart energy systems in EU as a whole - a review of previous studies

Igor Krupenski: Converting the heating system of the historic center of Tallinn (Old Town) to a district heating system

Graeme Maidment: The generation gap! Are we using the correct terminologies in the sector?

09:00-10:30 Room: Bondestuen

IEA DHC Annex TS4 Special Session

Chair: Ralf-Roman Schmidt

Session keynote Dietrich Schmidt: Digitalisation in district heating supply – with data to optimised systems and new business opportunities

Michele Tunzi: Digitalization of Demand side as the enabler for the transition towards 4th Generation district heating (4GDH)

Pakdad Pourbozorgi Langroudi: A Combi-Model for Failure Prediction of the Pre-Insulated Pipes in District Heating/Cooling Networks

Jakob Fester: Algorithms for assessing the condition of district heating service pipes exploiting GIS data, data from smart meters and soil temperature measurements

Ralf-Roman Schmidt: The AIT DigitalEnergyTestbed: An open test environment for digitalization solutions for integrated district heating networks

10:30-11:00 Coffee break

8th International Conference on

Smart Energy Systems

4th Generation District Heating, Electrification, Electrofuels and Energy Efficiency

PROGRAMME AALBORG

WEDNESDAY 14 SEPTEMBER 2022

Parallel sessions 21-24

11:00-12:30 **Room: Musiksalen**

Session 21: 4th Generation District Heating concepts, future district heating production and systems

Chair: Daniel Møller Sneum

Session keynote Ieva Pakere: Multi-source district heating system optimisation trough technical, economic and life-cycle analyses

Ana Catarina Marques: Driving success towards zero carbon energy targets for UK's Local Authorities

Flemming Bligaard Pedersen: Cost-effective Solar Powerplant delivering flexible electricity and district heating on demand

Hannes Poier: Demonstration of large scale solar district heating integration with storages and biomass - synergies and challenges

11:00-12:30 **Room: Gæstesalen**

Session 22: Smart energy systems analyses, tools and methodologies

Chair: Anton Ianakev

Session keynote Malte Schäfer: Life cycle oriented decision support for companies to reduce electricity-related greenhouse emissions

Alessandro Mati: Assessment of paper industry decarbonization potential via hydrogen based technologies in a multi energy system scenario : a case study

Shivangi Sachar: Wind energy potential assessment for the city of Nottingham using Weibull distribution estimation

Shubham Shubham: Feasibility study of different vertical axis wind turbines for wind conditions in the city of Nottingham

11:00-12:30 **Room: Laugsstuen**

Session 23: Integrated energy systems and smart grids

Chair: Hironao Matsubara

Session keynote Leif Gustavsson: A sustainable replacement for diesel trucking: Comparing battery electric and biofuel trucks

Emanuela Marzi: Assessment of Power-to-Gas integration for energy system flexibility accounting for forecast uncertainties

Hiroaki Onodera: Renewable Energy Systems Considering Profitability of PtG and PtL - a Case Study of Japan

Yudha Irmansyah Siregar: Assessment of transport electrification and district cooling towards smart energy systems in hot climate countries

11:00-12:30 **Room: Latinerstuen**

IEA EBC Annex 84 Special Session

Chair: Konstantin Filonenko

Session keynote Anna Marszal-Pomianowska: IEA EBC Annex 84: Demand Management of Buildings in Thermal Networks

Anna Kallert: IEA EBC Annex 84: Demand Management of Buildings in Thermal Networks – Case Studies including DH and DC Systems

Tijs Van Oevelen: Testing a smart controller for district heating systems : Results from an Italian case study in the TEMPO project

Konstantin Filonenko: Evaluation of district heating operation using flexibility function and Functional Mockup Interface

12:30-13:30 **Lunch and networking** **Restaurant**

13:30-15:30 European energy security and the war in Ukraine - 2nd plenary session chaired by Professor Poul Alberg Østergaard **Europahallen**

Plenary Keynotes:

13:30-13:45 **Professor Brian Vad Mathiesen**: Energy Efficiency First - REPower EU 2030 and 100% renewable energy in 2050 for Europe

13:45-14:00 **Connie Hedegaard, former EU Commissioner and Minister for Environment, Climate and Energy:** We know both the Danish targets and the EU's Fit for 55. But are our systems fit for implementation?

14:00-14:15 **Professor, Dr. Andreas Löschel:** After the "Zeitenwende" (turn of the times) is before the test - The path to climate neutrality between the Ukraine war and the coal phase-out

14:15-15:00 Questions and debate

15:00-15:20 Best Presentation Award Ceremony by Professor Poul Alberg Østergaard

15:20-15:30 Closing by Professor Henrik Lund

Technical Tour: Visit to Nordjyllandsværket – North Jutland Heat and Power Station

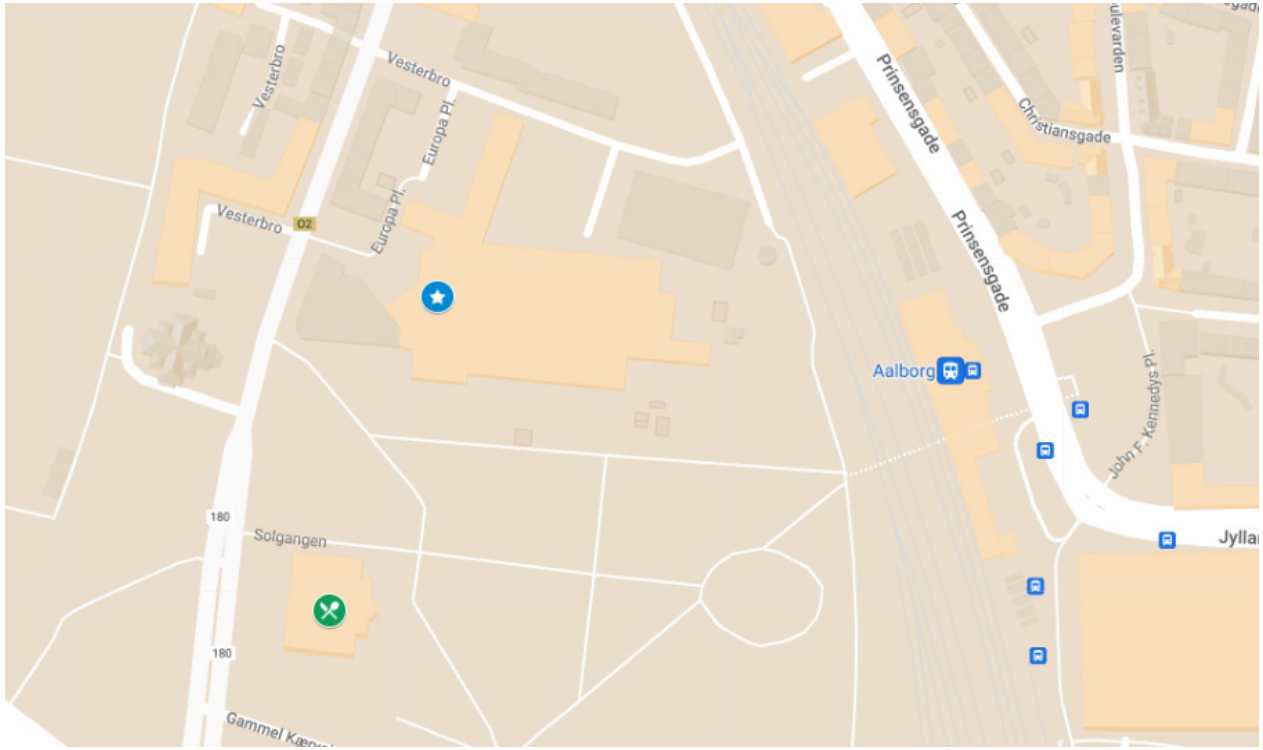
Thursday 15 September 2022
8:15 - 11:30

The mega size coalfired CHP plant provides heat and power to the city of Aalborg. It is under a tremendous transition to become a renewable energy living test centre – Norbis Park – and a fossil free heat and power producer in 2025 introducing mega size heatpumps, large storage dams, PtX facilities, cooling and other technologies avoiding biomass burners.

More information at conference website

Map of Aalborg

Conference area

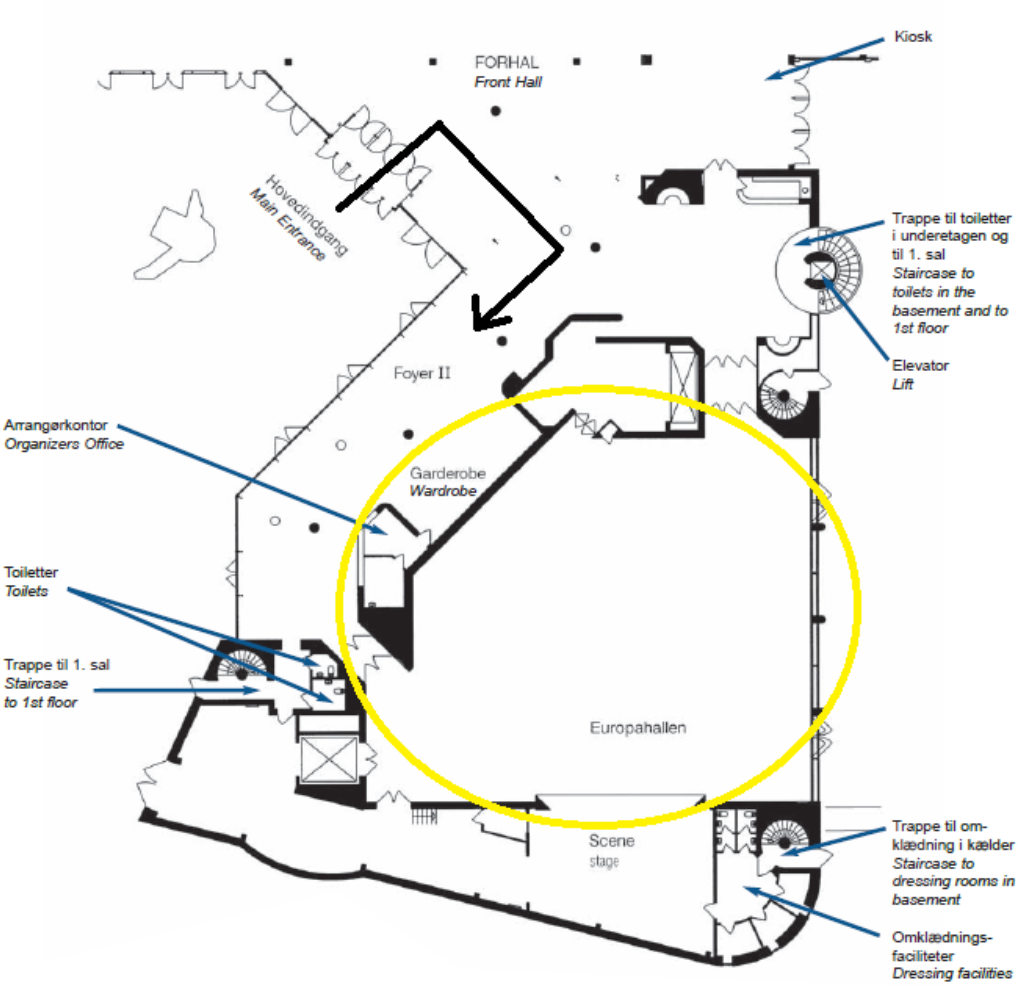


Conference dinner venue

Conference venue

Maps Conference Venue (AKKC)

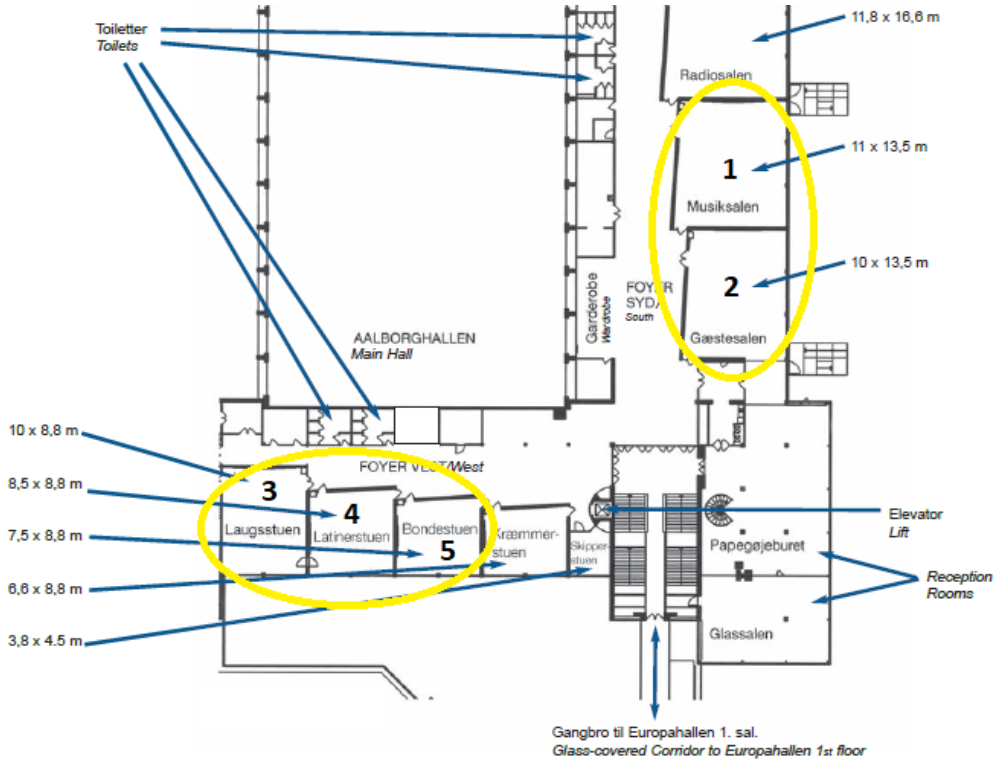
Plenary sessions take place in **Europahallen** on the ground floor. Turn right from the main entrance.



Ground floor

Parallel sessions take place on the first floor – in these rooms:

1. **Musiksalen**
2. **Gæstesalen**
3. **Laugsstuen**
4. **Latinerstuen**
5. **Bondestuen**



First floor

energyPRO

The leading software for techno-economic modelling and analysis of complex energy systems

EMD International

Gold sponsor of the SES Conference

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.

Kamstrup is a leading industry player in district heating and is driven by unlocking the enormous potential of using data-driven solutions and services to connect the entire value chain from production to buildings and end-users … and vice versa. Digitalisation is key to enable integration of renewables and waste heat, to ensure security of supply in an energy efficiency context and not least to make district energy an attractive offering to the end-users.

”We are happy to once again take part in the SES Conference as sponsor. Our focus is on developing data-driven solutions and services that enable utilities to optimise their business and grow the district heating footprint. We are excited to be contributing to reaching a more energy sustainable and efficient energy supply and realising the truly intelligent and integrated energy system of the future” says Steen Schelle Jensen, Head of Business Development, Heat/Cooling at Kamstrup.

In 2021, Daniel Møller Sneum was happy to receive his award for Best Presentation sponsored by Kamstrup and Logstor. Photo: Peter Kristensen

We take our role as a green company very seriously.

We believe that we all play an important role in reducing the energy consumption, and in developing an energy society that counter fights CO_2 emission and has no negative impact on our environment.

We believe that society must be much better at recycling materials and we believe that we need to incorporate recycling into new pre-insulated pipe projects from the outset. Through several green projects, we have proven that our vision which aims at 100 % recycling and circular economy holds true.

We do not only care about the flow of hot water in our pipes, whether this is produced from fossil fuel or renewable sources. We also care about how pre-insulated pipe systems are made in a sustainable way to enable the best and cleanest way of heating.

"Based on the above, our green vision goes beyond the basics, so rest assured that we will keep pushing boundaries, thus innovating for our customers and for a better tomorrow", says Terry Mc Givern, Managing Director for Kingspan-LOGSTOR.

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Grundfos – silver sponsor of the SES conference

Grundfos develops, produces and sells pump solutions, which help reduce water and energy related challenges globally.

An annual production of more than 16 million pumps positions the Grundfos Group as one of the world's largest pump manufacturers. Grundfos has more than 20,000 people and 60 sales companies around the world.

In district energy we are relentlessly ambitious in optimizing our solutions and we work with all decision makers to develop the most reliable and efficient solutions.

A new intelligent solution is Grundfos iGRID that helps district heating companies reducing their heat losses and effectively integrate sustainable energy sources. With a demand-driven approach, we create low temperature city zones that deliver exactly the temperature required in the buildings – nothing more and nothing less.

More to be shared during the seminar…

GREEN ENERGY ASSOCIATION SILVER SPONSOR OF THIS YEAR'S CONFERENCE

Green Energy Association

brings people with competencies on district heating together

Green Energy Association is the thinktank of the Danish district heating industry and DH-plants. Our goal is to create a knowledge center for tomorrow's district heating topics.

Green Energy Association has already set several political agendas and created analysis results for the benefit of the export industry and district heating plants. Among the results are:

- Distribution of large heat pumps in district heating for heating and cooling purposes
- Initiated the digital transformation in district heating, e.g. for optimizing the district heating plants
- Initiated geothermal energy utilization
- Initiated the use of surplus heat from, industry, supermarkets, data centers and Power to X

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Previous winners of the Best Presentation Awards

Best PhD/Postdoc Presentation:

2021: Daniel Møller Sneum, Technical University of Denmark

2020: Martin Heine Kristensen, Affaldvarme Aarhus

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:

2021: Kristina Lygnerud, Halmstad University

2020: Matteo Giacomo Prina, EURAC Research

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

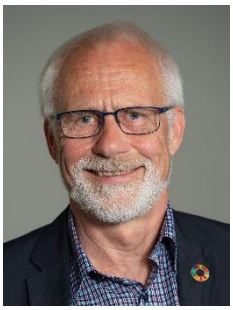
Professor Henrik Lund is Editor-in-Chief of Elsevier's international journal ENERGY and a world leading scientist. He is ranked among the top 1% researchers on the world on the Thomson Reuter's list of highly cited researchers. He holds a PhD in "Implementation of sustainable energy systems" (1990) and a senior doctoral degree in "Choice Awareness and Renewable Energy Systems" (2009). Henrik Lund has 40 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 – among others the 4DH research centre. 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 500 books and articles.

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

Professor Brian Vad Mathiesen 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 (2015-2021), thus among the top 1% most cited researchers globally. Among other positions, he has been part of the EU Commission expert group on electricity interconnection targets and the 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 was the Principal Investigator (PI) of the RE-INVEST and sEEnergies projects. He has been PI, work package leader and participant in more than 75 research projects. In 2012 he founded the MSc programme in Sustainable Cities at Aalborg University. 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), a board member at The Danish Energy Technology Development and Demonstration Programme (EUDP) and deputy chairman of the Advisory Board of the CIP Foundation.

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. His research competence includes 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 multiple research projects focusing on renewable energy scenarios, integration of renewable energy sources into the energy system and framework conditions for renewable energy scenarios. He has contributed to more than 100 scientific journal articles in highly reputed journals in addition to reports and other non-peer reviewed work. He is editor-in-chief of the International Journal of Sustainable Energy Planning and Management and co-editor of a number of other journals. Furthermore, Poul A. Østergaard is the Head of Study Board of Planning and Land Surveying at Aalborg University as well as the Programme Director and a distinguished teacher of the M.Sc. programme in Sustainable Energy Planning & Management at Aalborg University.



Hans Jørgen Brodersen, Senior Project Manager, Energy Cluster Denmark

Hans Jørgen Brodersen is present Senior Project Manager at Energy Cluster Denmark and formerly Project Director at Clean Cluster energy. He holds a Master of Science in "International Environmental and Energy Planning" from Aalborg University and has more than 30 years of Project management and teaching experience within Environmental, Technological and Energy Planning. He has held more Head of Center positions at and with Aalborg University within Waveenergy and Technology development. Centers that focus on Research and Technology Innovation in cooperation with the private and public sectors. He has formerly also been Consultant in his own company and at Deloitte, where Energy and Environmental Management systems and organizational technology change in the private sector has been the drive of his work. He is external Examiner at Aalborg University. Among others, he has also been involved in the making of the Danish Society of Engineers' proposal for a future 100% Renewable Energy Plan for Denmark, And before that chair and organizer of the International Europe Sustainability conferences with International business organisations like World Business Sustainability Council.

ABOUT RE-INVEST

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.

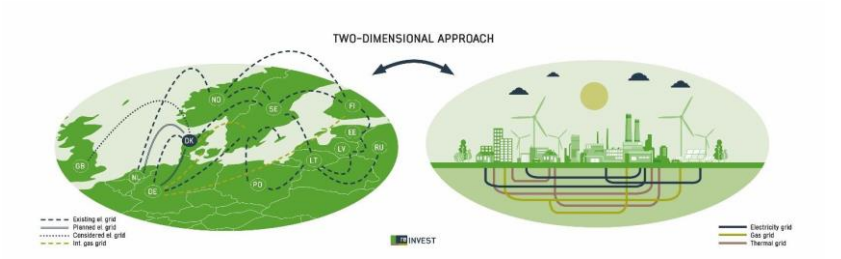
RE-INVEST aims at designing robust and cost-effective investment strategies that will facilitate an efficient transformation towards a sustainable or 100% renewable energy system in Denmark and Europe.

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.

ABOUT SEENERGIES

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

Jesper Møller Larsen will give a keynote speech on Using the right energy, right in Aalborg – taking the common energy solutions to the next (green) level

Jesper Møller Larsen is manager and responsible of District Energy Systems in Aalborg Forsyning including the District Heating, City Gas distribution and District Cooling services. Mr. Larsen has been working in the energy sector for more than 20 years, especially working with the development of the newest generations of DH systems and focusing on the expansion of the district energy networks and of course the transition of the entire sector to renewable energy.

David Dupont-Mouritzen will give a keynote speech on Power-to-X as a key for the green transition.

David Dupont-Mouritzen is Project Director for CIP's HØST PtX Esbjerg project. He holds an M.Sc in Geography from the University of Copenhagen and from his previous work experiences as director for the Fisheries and Maritime Museum in Esbjerg, and as director for Åfjord Utvikling – a development company North of Trondheim, Norway, he has extensive experience within public affairs, communication and strategy as well as project management, business development and a strong focus on sustainability.

Samir Abboud will give a keynote speech on Industrializing geothermal energy for urban district heating.

Samir Abboud is a lawyer by background and has more than 20 years of experience from Maersk Oil and Maersk Drilling in various legal, commercial, and managerial positions. Samir joined Innargi as CEO in 2018. The company's ambition is to turn geothermal into a reliable, robust, risk-free, and affordable alternative to fossil fuels.

Sven Werner will give a keynote speech on The four generations of district cooling – a categorization of the development in district cooling from origin to future prospect.

Sven Werner is Professor of Energy Technology at the School of Business, Engineering and Science, Halmstad University. Previously, he worked at the Borås Energi public utility company and the Fjärrvärmebyrån organisation. Sven Werner's knowledge and research results are visible in several scientific journals and reports, in textbooks and through numerous lectures and have been communicated worldwide through various activities and presentations.

Connie Hedegaard will give a keynote speech with the title We know both the Danish targets and the EU's Fit for 55. But are our systems fit for implementation?

Connie Hedegaard was the European Commissioner for Climate Action from 2010 to 2014, during which she led the negotiations towards the adoption of the EU 2030 Climate and Energy Framework. As EU Commissioner, she was also responsible for the 2050 Roadmap for moving to a low carbon economy and represented the EU in the international climate negotiations. Before that, Connie Hedegaard was Minister for Environment and Minister for Climate and Energy in Denmark. With two decades of experience in international and domestic executive policy making, Connie Hedegaard is today assuming several key positions in support of a low-carbon and green economy.

Andreas Löschel will give a keynote speech on After the "Zeitenwende" (turn of the times) is before the test – The path to climate neutrality between the Ukraine war and the coal phase-out.

Professor Andreas Löschel holds the Chair of Environmental/Resource Economics and Sustainability at the Ruhr University Bochum and is a Senior Fellow at the Alfried Krupp Institute for Advanced Study in Greifswald. Since 2011, he has been the chairman of the Expert Commission of the German Government to monitor the energy transformation. He also directs the Virtual Institute Smart Energy North Rhine-Westphalia (VISE). Andreas Löschel is a lead author of the Intergovernmental Panel on Climate Change (IPCC) and a member of the German National Academy of Science and Engineering (acatech). For outstanding research in economics, he received the German Economics Prize of the Joachim Herz Foundation 2022.

Brian Vad Mathiesen will give a keynote speech with the title Energy Efficiency First - REPower EU 2030 and 100% renewable energy in 2050.

Brian Vad Mathiesen is Professor in Energy Planning and Renewable Energy Systems at Aalborg University, and is one of the leading researchers behind the concepts of Smart Energy Systems and electrofuels. He is on Thomson Reuters Highly Cited list, a global list of the top 1% cited researchers; a member of the EU Commission expert group on electricity interconnection targets in the EU, and Principal Investigator (PI) of the RE-INVEST and sEEnergies projects. His research focuses on the technological and socio-economic shift to renewable energy (RE), large-scale integration of variable resources and the design of 100% RE systems.

Plenary Keynote: Jesper Møller Larsen

Manager of District Energy Systems, Aalborg

Using the right energy, right in Aalborg – taking the common energy solutions to the next (green) level

Abstract

In order to reach the ambitious levels of 100% renewable energy district energy systems in the cities after 2030 Aalborg Forsyning has adapted a comprehensive strategy paving the way towards the green future.

The strategy relates to both the consumption of energy in the form of district heating, district cooling and citi-gas, as well as how the aforementioned energy services are delivered and produced. In Aalborg, which is a traditional industrial city, more than 50% of the district heating has for many years been produced with the help of fossil energy in the form of coal, while the entire city gas supply has been based on fossil natural gas. But the desire to convert to green energy solutions before 2030 has set a major conversion in motion.

On the consumption side, work is especially being done with temperature optimization and energy savings – therefore, in the future, district heating will be able to be delivered at a maximum of 60 degrees Celsius to satisfy the needs for comfort amongst the customers. The lower temperatures in the district heating network and higher temperatures in the cooling systems mean a tremendously better utilization of the future's energy sources such as ambient heat/cooling from air and water-sources in particular (lake, seawater, groundwater etc.).

In Aalborg, a large part of the district heating of up to approx. 30% has already been produced using surplus heat from industry and in the future RE system this proportion is expected to increase all the way up to between 40-50%. There is still a lot of untapped potential and at the same time the synergy between the cooling and heating systems means that the cooling of some processes automatically generates heat that can be used in the district heating system which today supplies district heating to 99% of the customers in the district heating area.

Plenary Keynote: David Dupont-Mouritzen

Project Director, HØST PtX Esbjerg

PtX is key for the green transition

Abstract
How can green electricity, water and air contribute significantly to the green transition? How does a large-scale PtX plant fit in to our grid system? And what are the possibilities to create local sector connections to water and heat supplies respectively? Esbjerg has the possibility and potential of creating a new growth adventure based on the green transition phase.

HØST PtX Esbjerg is a leading, Danish Power-to-X (PtX) project, deploying large-scale industrial use of electrolysis-technology on GW-level to produce ammonia. The ammonia plant will be powered by green electricity from renewables, harvesting the kinetic energy from wind and solar. Based on this CO2-free production process, HØST PtX Esbjerg will be able to offer green ammonia to the market for use in fertilizers and in fuels. Thereby, HØST PtX Esbjerg is opening the door to decarbonization of hard-to-abate sectors such as shipping, agriculture and industrial applications. Further, excess heat from the plant will be used for district heating of app. 15,000 households, reducing the carbon footprint of the local utility company, DIN Forsyning. Moreover, the 1GW plant is the ideal, green offtake companion to the continued build-out of low-cost, renewable electricity generation capacity in the North Sea.

HØST PtX Esbjerg will be among the first gigawatt-scale PtX facilities in Europe, contributing to the much-needed acceleration of the decarbonization journey towards carbon neutrality in 2050. Moreover, it will be a key driver for the establishment of a new industry within next-generation renewables in Esbjerg and in Denmark.

Plenary Keynote: Samir Abboud

CEO, Innargi

Industrializing geothermal energy for urban district heating

Abstract
As the globe is getting warmer, it's time to rethink the way we heat our urban buildings. Large-scale geothermal heating plants can provide local baseload renewable energy for district heating companies and accelerate the independence of gas and coal.

There are three main reasons why the breakthrough for geothermal as an energy source for district heating is now:

1. In the future, power will be produced by wind and solar which does not generate waste heat to heat our houses. This opens a demand for new heat production technologies.

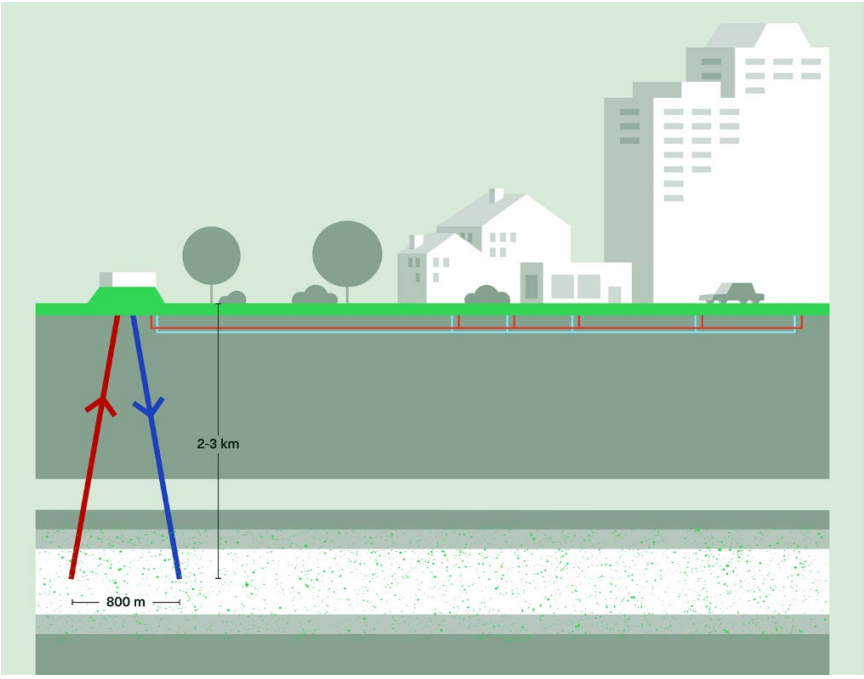
2. Historically many projects have failed due to either poor planning and executing in the exploration phase or poor production management in the operating phase. With experience and competencies from the oil and gas industry and taking full project responsibility from 'cradle to grave', Innargi removes the risks from the district heating company and consumers, making geothermal energy an attractive product.

3. The price has been reduced when talking large scale geothermal heat production because the process can be industrialized.

Innargi has developed and patented a modularized surface facility solution that has a very small physical footprint. The small footprint makes it easier to integrate in an urban environment. The modularization and standardization help us drive down costs and reduces the time on-site in the construction phase. It also reduces downtime if a major repair is to be made - then the module can be lifted out through the roof of the building and repaired off site.

The geothermal brine is produced and injected via a standard pair of wells, and what is going on in the reservoir is basically a large waterflood - there is just no oil involved. That is why using experience and competencies from the oil and gas industry is an essential part of unlocking geothermal as a renewable energy source for district heating.

District heating is one of the cheapest ways of achieving the transition to green energy in large cities. But district heating is only green when the energy sources are green and only reliable when the energy sources are available as baseload 24/7 – 365. Geothermal energy is a large renewable energy source waiting to be tapped. So, let's rethink heating!



Plenary Keynote: Sven Werner

Prof. at Halmstad University

The four generations of district cooling - a categorization of the development in district cooling from origin to future prospect

Abstract

Research into new advanced district heating concepts has increased since the first four generations of district heating were defined in 2014. This definition created a common framework for research and industry alike, and pointed to potential futures for district heating which could benefit from low-temperature heating in buildings. The fully developed fourth-generation district heating includes the cross-sectoral integration into the smart energy system. This paper defines four generations of district cooling to make a similar useful framework for district cooling. The first generation being pipeline refrigeration systems that were first introduced in the late 19th century, the second generation being mainly based on large compression chillers and cold water as distribution fluid, the third generation having a more diversified cold supply such as natural cooling, and the fourth generation combining cooling with other energy sectors sometimes into a renewable energy-based smart energy systems context, including combined heating and cooling.

Reference

P.A. Østergaard, S. Werner, A. Dyrelund, H. Lund, A. Arabkoohsar, P. Sorknæs, O. Gudmundsson, J.E. Thorsen, B.V. Mathiesen: “The four generations of district cooling - A categorization of the development in district cooling from origin to future prospect”, Energy vol. 253, August 2022

Plenary Keynote: Connie Hedegaard

Former European Commissioner, Minister for Environment and Minister for Climate and Energy

We know both the Danish targets and the EU's Fit for 55. But are our systems fit for implementation?

Abstract
Unintendedly, Putin has pushed the green transition in Denmark and the EU. Following the war in Ukraine, we have declared targets, partial aims and visions for large-scale facilities, technological leaps, and investments, like never before. But are our systems capable of delivering at the speed and scale demanded? Among other steps, the transition will require an extended cooperation between market and state and between the public sector and the private companies. How can the systems operate under complex conditions? These are some of the questions that Connie Hedegaard will bring up in her keynote speech.

Plenary Keynote: Andreas Löschel

Prof. Dr. at Ruhr-Universität Bochum

After the "Zeitenwende" (turn of the times) is before the test - The path to climate neutrality between the Ukraine war and the coal phase-out

Abstract
Europe has committed to climate neutrality mid of the century. The presentation looks at the path to climate neutrality from an economic perspective. What can a strategy for the energy transition look like between the Ukraine war and the coal phase-out? It is clear that a readjustment of the energy policy triangle of affordability, environmental compatibility and security of supply is required and that the resilience of the energy system will be of outstanding importance. What role do energy saving, electrification, expansion of renewables, hydrogen and synthetic fuels, carbon capture and storage play on the path to climate neutrality? From an economic perspective, what is the appropriate regulatory framework that drives climate protection, green innovations and infrastructure expansion while at the same time ensuring competitiveness and energy sovereignty? Only if the readjustment of the energy policy target triangle succeeds, will the acceptance for energy transition and climate protection be maintained among the population. There are no easy solutions. After the turning point is before the test.

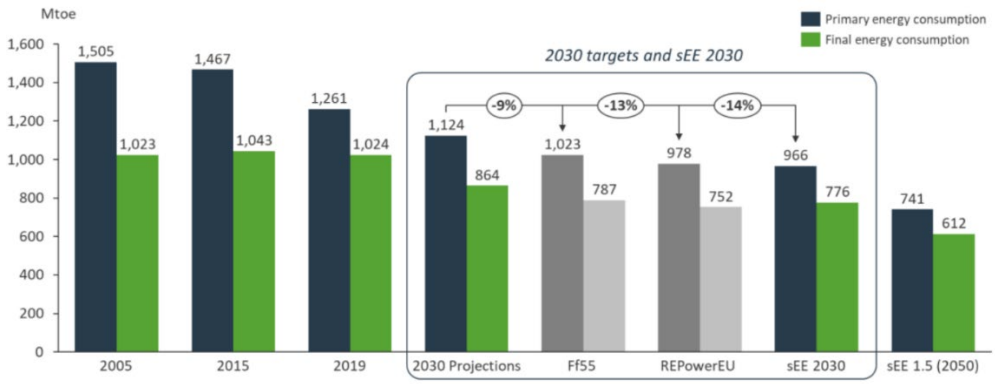
Plenary Keynote: Brian Vad Mathiesen

Prof. at Aalborg University

Energy Efficiency First - REPower EU 2030 and 100% renewable energy in 2050 for Europe

Abstract

The energy crisis started last summer, long before the Russian invasion of Ukraine. In this presentation, the newly finished results in the sEEnergies project focus on inputs for dealing with the energy crises, REPowerEU and Fitfor55. The primary aim of the project was to quantify energy efficiency in a climate-neutral energy system in 2050. The project has overall EU results as well as results for all EU27 countries including the UK. Sectoral results are presented for buildings, transport and mobility, industrial process as well as on grids. This enabled the development of 28 smart energy systems for a clean, smart, and secure European energy system driven by significant energy savings, the deployment of renewable energy, all in the focus of the Energy Efficiency First Principle. Energy efficiency must have priority in planning processes and investments. sEEnergies answers essential questions and provides policy recommendations regarding effective energy efficiency measures and identifies where renewable energy is more cost-effective than further end savings. (www.seenergies.eu)



Professor Andra Blumberga is an expert with many years of experience in the fields of energy efficiency and system dynamics modeling. For the last 20 years, A. Blumberga has developed an academic career at RTU, where since 2012 she has been the Vice-Dean of Science in the RTU FEEE.

The Profile of a "Hard-to-Reach" Energy Consumers of the Baltic and Nordic States in the Process of Energy Transition

Andra Blumberga, Riga Technical University
Kertu Lepiksaar, Tallinn University of Technology
Ruta Vanaga, Riga Technical University
Jagruti Ramsing Thakur, KTH Royal Institute of Technology
Anna Volkova, Tallinn University of Technology

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The long-term climate action goal in the EU is to reach carbon neutrality by 2050. And it faces questions of fairness and inclusiveness of all actors of the remodeled energy system. Energy system models are used to map transitions to low carbon societies and to advise policy and planning on how to achieve them. While such models include high levels of techno-economic detail, they often exclude the social factors that will actually shape the process of energy transition. This may lead to designing solutions neither publicly nor politically feasible and fail to consider social justice implications. This could, at best, make it significantly costlier, at worst, impossible to reach long term decarbonization targets. Thus, it is essential to study the adoption of these measures by the end-users. Social-energy research considers the integration of behavioral and perception facets with features of a consumer in the process of implementation of energy transition. An inclusive study on consumer behavior types in relation to their energy consumption pattern was launched. One such class includes 'Hard to reach consumers (HTR)' who are difficult to be influenced to instigate change in their energy consumption for numerous reasons. It is essential to consider such types of consumers, to identify their behavioural patterns and other characteristic traits, thus helping to meet the local and global climate goals. Paper identifies what are the most common hard-to-reach energy user groups in the Baltic and Nordic states including, how complex are these audiences, what are the main barriers and potential drivers to shift their attitude towards the sustainable development (energy efficiency in particular) and to change their energy consumption behavior. Both theory and practical cases are studied. A quantitative national data analysis from scientific literature and stakeholders (energy companies, municipalities, developers etc.) is carried out. HTR energy user groups in the Baltic-Nordic region are identified, characterized and classified, incl. energy users that are either HTR physically, or hard to engage or motivate for energy efficient behavior change.

Gained results are of high value to policy makers as well as to executive authorities implementing the energy transition.

Keywords: Climate goals, carbon neutral society, social factors, energy justice, inclusiveness, energy transition actors, end - users, prosumers, diffusion of energy efficiency technologies

Casey Cole is CEO of Guru Systems, a UK-based technology company focused on decarbonisation of heat. He has 20 years' experience in software and low carbon energy. Casey also chairs the board of Heat Trust, the UK's stakeholder-led customer protection scheme for heat networks.

Digitalising heat network commissioning - using apps to bridge the skills gap

Casey Cole, Guru Systems

Casey Cole (presenter) casey.cole@gurusystems.com

The UK must increase the proportion of heat delivered over heat networks from about 2.5% today to at least 20% by 2050 if it is to cost-effectively meet its legally binding carbon targets. However, even where heat networks are well-designed, they are often not properly commissioned. This results in high heat loss, increased fuel use, increased costs for both the network operator and the consumer, and poor customer experience. Real-world results from a project delivered by Guru Systems in collaboration with the UK Government showed that proper commissioning alone can reduce heat losses on networks by nearly 70%.

To address this inefficiency risk, rather than rely on commissioning certificates, it is increasingly common for developers of new UK heat networks to require Acceptance Testing, a process of using measured data and photographic evidence to verify commissioning outcomes. This requirement is expected to be enshrined in regulation within the next few years. Unfortunately the expertise to carry out such tests is very limited, thereby driving up cost and creating a significant skills gap.

Guru Verify is a mobile app and web app designed to make Acceptance Testing quicker and more cost effective by making it more transparent to all stakeholders and enabling less skilled technicians to reliably follow the process. The web app allows the developer or their advisors to define the test criteria and check dwelling status remotely, track progress across the entire site online and access results and photographic evidence for as long as is needed.

Guru Verify has already been used to verify commissioning on more than 1000 homes connected to UK heat networks. The mobile app has proven to make the Acceptance Testing process much clearer so that it's now possible to be undertaken by non-expert engineers. The web app has proven to save significant time both across the preprocessing and postprocessing stages. Heat networks where all homes have undergone Acceptance Testing using the Guru Verify app outperform their design parameters, including routinely achieving return temperatures of 30 degrees.

Keywords: digitalisation, skills gap, low temperature heat networks, mobile apps

Rémi Delage studies the complexity of energy systems using analysis techniques from nonlinear science to support the development of models and sustainable solutions.

Cluster analysis of Japanese households based on energy consumption mix

Rémi Delage, Tohoku University, Graduate School of Engineering; Toshihiko Nakata, Tohoku University, Graduate School of Engineering

Rémi Delage (presenter) delage@tohoku.ac.jp

Sector integration is one of the major components considered when designing future smart energy systems toward sustainability. Due to the lack of data, current partitioning of consumers into residential, commercial, industrial, and transportation sectors is based on assumptions on their respective energy demand. In reality though, there is a diversity in preferences and behaviors so that consumers from the same sector may have different demand and consumers from different sectors may have similar demand. With the increasing amount of individual data, it is becoming possible to study this diversity and more accurately partition consumers using advanced analysis techniques such as clustering. However, while this approach does allow for an accurate grouping, the complex mechanisms at the roots of identified clusters are still unclear. Indeed, energy demand depends on multiple integrated factors such as social, economic, political, as well as environmental conditions. The present study uses households' data provided by the Japanese Ministry of the Environment with the objective of finding patterns associated with residential energy consumption profiles. After identifying clusters, we look for statistically significant specificities in the corresponding households' data including information such as the geographical location, number and age of residents, annual income, equipment and vehicles. Several observations can be drawn from this analysis. The probability distribution of households based on their energy consumption seems to be log-normal so that clusters are revealed by first applying a logarithmic or similar transformation. K-mean clustering, which is the standard clustering technique in energy systems study, fails to correctly identify the clusters when compared with density-based clustering in our case. Kerosene use appears prominent in coldest regions as it is cheaper than electrical heating alternatives. Only the area with highest population density have access to city gas, households from less populated area rely on LP gas. Households using only electricity live in the most recent buildings and are not significantly more present in specific regions.

Keywords: Residential sector, Energy mix, Clustering

Hermann Edtmayer is a research associate at Graz University of Technology, Institute of Thermal Engineering and has his main field of research in the topics of renewable urban energy supply, building energy modelling and simulation and spatial energy planning.

Analysing the thermal energy demand of development scenarios of a city district

Hermann Edtmayer, Lisa-Marie Fochler, Thomas Mach, Institute of Thermal Engineering, Graz University of Technology; Jennifer Fauster, Eva Schwab, Institute of Urbanism, Graz University of Technology;

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In contemporary urban planning an efficient use of resources is key. Therefore, information about the thermal energy demand of the area to be worked on is very important. Ideally, comprehensive data on both aspects, the status quo and future scenarios is at the disposal of the stakeholders involved. However, there is often little information on thermal energy demand in the status quo and data on possible development scenarios is usually not available at all.
Here we present the analysis of the thermal energy demand of a city district in Graz, Austria. For this, we used a multi-tool workflow for high-resolution urban building energy modelling (UBEM). We implemented the status quo and two different development scenarios into an urban information model (UIM). The scenarios were developed from the perspective of strengthening the quantity and quality of green spaces and to foster a circular use of resources in the buildings. In the in the urban simulation model, we varied parameters like the outdoor temperature prediction for Graz (IPCC RCP8.5), the building hull quality and usage class or the amount of gross floor area. The buildings were designed in 3D CAD in single-storey resolution using the BIM Tool IfcSpace. The energy relevant urban data which was provided by different stakeholders at the city of Graz was then stored in the CAD geometry. Hereafter we used an automated urban building modeler and the building simulation tool IDA ICE to calculate the heat energy (heating and domestic hot water) and the cooling energy demand in a dynamic building energy simulation for the timespan of one year.
As results the calculated heat and cooling energy demand for the status quo as well as for development scenarios for the year 2030 and 2050 are available in hourly mean values for each building in the district. In addition, the data was further processed in the form of georeferenced map representations, see Fig.1, and overall values. Thus, the results are easily available to the stakeholders and decision-makers involved and form the basis for the integrative development of the city of Graz.
The research work is part of the project ECR-Smart City Graz 2020 and funded by the city of Graz and the government of Styria.

Keywords: urban building energy modelling, thermal energy demand analysis, integrative city district development

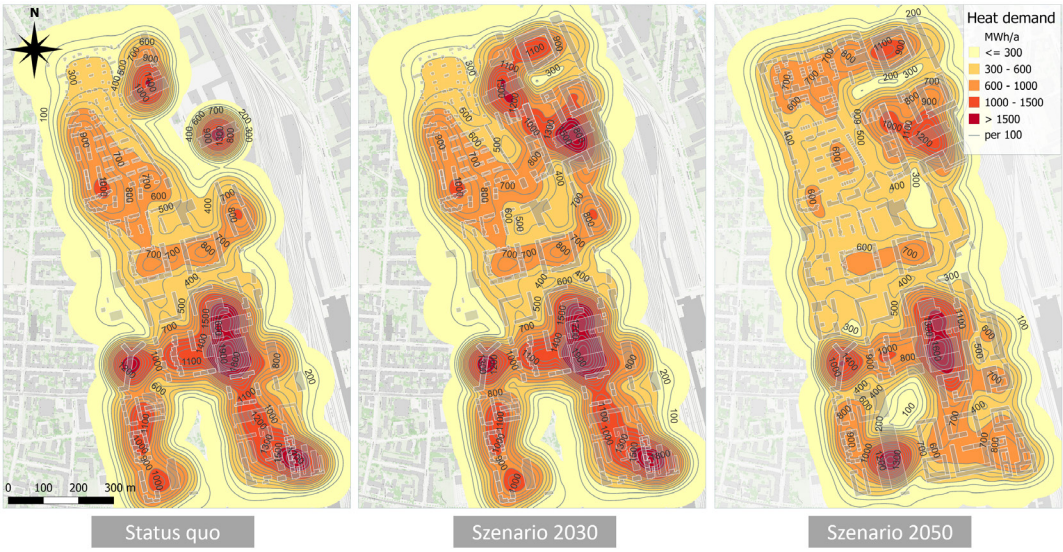

Figure 1: Comparison of status quo and the development scenarios of the district under consideration; heat map and contour plot of the calculated heat energy demand (heating + domestic hot water)

The study addresses the challenges like space and investment constraints in Bangladesh for renewable energy development by introducing VNM, considering its digitalization progress

Virtual net-metering and citizen investment for boosting energy transition in the cities of emerging economies: A case study on Bangladesh

ASM Mominul Hasan, Department of Energy and Environmental Management, Europa-Universitaet Flensburg

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This study explores the Virtual Net-metering (VNM) option for enabling inclusive investment opportunities in renewable energy for self-consumption. Therefore, the study focuses on consumers who cannot participate in traditional net-metering policy due to space constraints, such as households and businesses in multi-family and multi-story buildings. The study develops and proposes a 2-step systematic approach to determine the potential and benefits of VNM for various RE systems, especially solar energy. The first step is socket parity which compares electricity tariff and the cost of wheeled energy from remote power plants. And the second step determines the user benefits by calculating the net present cost (NPC) and discounted payback period. Afterwards, this approach was applied to perform a case study on Bangladesh, considering its simple electricity tariff structure (energy cost + wheeling charge + distribution costs + VAT + demand charge), availability of smart energy meters, and high population density. The result shows that the VNM can offer immediate benefits to certain consumer categories, such as commercial, industry, electric vehicle charging stations and households with high electricity consumption, based on their current electricity tariffs and energy consumption. For example, commercial consumers can save more than 50% of their electricity bills by investing in VNM enabled remote solar power plants with a discounted payback period of less than 6 years. Furthermore, in a sensitivity analysis, the wheeling costs are varied using Monte-Carlo simulations. The market size and the RE capacity integration potential in Bangladesh were estimated in a subsequent step. In this context, the suitability of adopting the existing government housing model for implementing VNM and community based remote power plants was discussed. The study identifies a significant potential to create momentum for citizen investments in the energy transition. The proposed approach can also be used for analysing VNM potentials in countries sharing similar characteristics.

Keywords: Virtual Net-Metering (VNM), Energy Wheeling, Remote Solar Power Plant (RSPP), Community Energy, Citizen Investment, Digitalization of Power System

He studied electrical engineering with a master in sustainable energy technology. After his master thesis on optimized energy modeling, he began as a researcher at Campus Feuchtwangen and works on decarbonization projects, develops tests for wallboxes and batteries and educate in the SES-master.

Analyzing the impact of Smart Energy Management Systems on the economy of various PV and battery systems for individual households

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Philipp Mascherbauer, Technische Universität Wien, Energy Economics Group, Gusshausstrasse 25-29/370-3, 1040, Wien, Austria

Songmin Yu, Fraunhofer Institute for Systems and Innovation Research, Breslauer Str. 48, 76139 Karlsruhe, Germany

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This paper evaluates the impact of smart energy management systems (SEMS) on the economy of various PV and battery systems for households living in single-family houses (SFHs) under different electricity tariffs.
For this, an hourly operation model for households that adopts PV and battery systems was developed, to calculate their energy cost, (1) without optimization as a Prosumer, or (2) with optimization based on the SEMS as a Prosumager. Taking the outside temperature, radiation, electricity price (static and variable), and feed-in-tariff as input, the model can simulate or optimize the hourly operation of technologies including PV, battery, heat pump while satisfying the households' demand of heating, cooling, hot water, and electricity for appliances. The heating and (optional) cooling dynamics in the building are modeled with a 5R1C model taking the building mass as thermal storage. The optimization is based on the technological flexibility supported by the battery, hot water tank, hourly variable coefficient of performance (COP) of the heat pump, and the thermal mass of the building.
Based on the calculation, the best configuration of a PV and battery system are identified for both prosuming and prosumaging households, and the impact of the SEMS is also presented. Then, this result is further discussed under different scenarios of electricity price (e.g. higher or lower, and static or dynamic tariffs) to provide support on the design on relevant policies.

Keywords: Prosumager, SEMS, PV, battery, energy optimization, economy, heat pump, building mass

Henrik Håkansson is a MSc and working as a research engineer at Fraunhofer-Chalmers Centre for Industrial Mathematics in Gothenburg, Sweden. He has a broad interest in applied machine learning and data analysis.

Model predictive control for heating systems when using demand tariffs

Emil Gustavsson, Fraunhofer-Chalmers Centre
Magnus Önnheim, Fraunhofer-Chalmers Centre
Henrik Håkansson, Fraunhofer-Chalmers Centre
Mats Jirstrand, Fraunhofer-Chalmers Centre

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Real-estate owners pay for district heating in the following two ways: consumption, measured in kWh; and demand, measured in kW. This means that the cost for utilizing district heating for a building is a function of both the total energy (consumption) utilized by the system and of the maximum power that the heating system has utilized (demand). This is a common economical model that the district heating suppliers employ in order to force the real estate owners to keep their maximum power on lower levels, and the term that is often used is demand charge tariffs. The reason for including demand charge tariffs is that the district heating supplier want to reduce the peak demands that occur in the system on specific occasions.

The traditional approach for a real estate owner to perform control of a building's heating system is by simple open-loop control that puts out a specified effect or feed temperature which only depends on the current outer temperature. A smarter way of controlling the system is by utilizing model predictive control (MPC) algorithms that models the building's behavior and controls the heating systems with specified objectives and constraints. With MPC one can employ the true economic model and hence try to minimize the cost (consumption and demand) of the real estate owner when controlling the heating system.

In this work we analyze how MPC algorithms are affected by the economical models that the heating supply companies utilize and demonstrate that it is possible to reduce the heating system cost for the real estate owner by introducing MPC problems that have both the consumption and the demand cost as objectives. We analyze what happens when one assumes that the demand charge tariff (the cost for the maximum demand) can be shared between a population of buildings instead of being charged per individual building and demonstrate that such an economic model can be beneficial both for the real estate owner as well as the district heating supplier since the coupled problem can plan and reduce the overall peak load of the district heating system. All evaluations and simulations are performed using real world data

from a population of buildings in Sweden where we currently are controlling the heating systems with our developed algorithms.

Keywords: model predictive control, district heating system, demand tariff, heating system control

Phd student of Cyber Physical Systems at Luleå University of Technology, Sweden.

Demand Response in Distributed Energy Systems of Systems Using Local-Cloud: An Approach towards Net-Zero Emissions

Salman Javed, Aparajita Tripathy*, Jan van Deventer, Cristina Paniagua, Sandeep Patil, Jerker Delsing, Luleå University of Technology, Sweden*

Salman Javed (presenter) salman.javed@ltu.se

Industry 5.0 is an extension of Industry 4.0 that enhances human comfort while improving productivity through automation and assures sustainability by promoting environmental protection and working toward net-zero emissions. District heating is one of Industry 5.0's application areas that impacts climate change. Hence, decreasing district heating's peak load or demand without jeopardizing end-user comfort is vital for society.

The Eclipse Arrowhead is an Industry 4.0 framework that uses a service-oriented architecture to create local cloud-based systems of systems that promotes late-binding, loose-coupling, cyber-security, and interoperability, independent of underlying protocols. To achieve Industry 5.0 objectives, we should increase the capabilities of the Arrowhead by introducing Artificial Intelligence at the Edge, which incorporates humans and the environment.

We propose an open-source vendor-neutral solution to enable buildings to participate in demand response within a distributed energy network. Each energy provider and each energy consumer become a local cloud. The solution uses the Arrowhead inter-cloud communication between Factory and SmartHome local clouds. The Factory cloud has an Energy Provider system that offers a microservice to provide the hourly price of district heating. The SmartHome cloud provides engineering redundancy and has two provider systems: an adapter for IoT devices (Z-Wave) with microservices to set the thermostat valves and obtain the indoor temperature, an AI Module that predicts setpoints based on environmental profiles. It also has an Intelligent Thermostat consumer system that obtains the current heat price via an inter-cloud and calculates the set-points using the price and AI predictions. As illustrated in the figure, it sends the calculated set-point to the appropriate thermostat valve via the Z-Wave Adapter. It also stores all the consumed data in the Arrowhead supporting core system, the DataManager system.

Our solution can reduce energy consumption while preserving user comfort. The novelty is real-time engineering redundancy and analytics for thermostat valve and hydronic radiator size using microservices. It also provides local and remote condition monitoring of devices and systems with environmental profiling.

Keywords: Demand Response, Eclipse Arrowhead Framework, Local Cloud, Net-Zero Emission, Industry 5.0, Z-Wave, Microservices

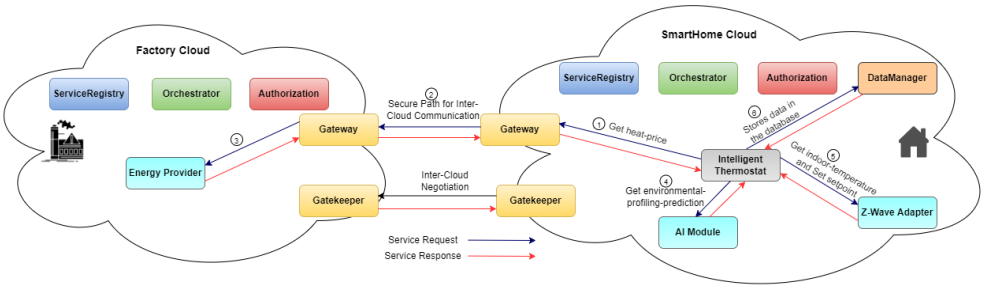

Figure: Service Exchange between smart energy systems using the Arrowhead inter-cloud communication

Joseph 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.

Design of district heating networks using a ring network and storage configuration – A case study using Comsof Heat

Joseph Jebamalai, Comsof; Kurt Marlein, Comsof; Jelle Laverge, Ghent University;

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District heating systems (DHS) are one of the most efficient means to heat buildings in the urban area. These systems are getting increasingly complex due to several factors such as addition of multiple sources, storage systems, and complex network design configurations. This makes it almost impossible to design these complex DHS manually. In this presentation, an automated solution to design these complex systems in a manageable manner will be discussed. Comsof Heat is a GIS-based automated district energy network planning and design tool. It uses intelligent algorithms enabling automated cost efficient network routing and dimensioning based on the network constraints and design choices provided by the user. It is capable of designing several 3rd and 4th generation network features such as multi-source integrated design, centralized or distributed storage configurations, and branched or ring network configurations. Furthermore, it is capable of designing features of a 5th generation ambient temperature network with distributed heat pumps in the building side. Currently, Comsof is doing research to automate the design of 2-way networks to add prosumers in the network.

A case study of designing a district heating system for a city in Belgium with ring network and storage configurations will be presented. The network will be designed using Comsof Heat for both centralized and distributed storage configuration. The network deployment cost and financial parameters such as NPV, IRR, and payback period will be estimated for the network. Sensitivity analysis will be carried out by varying several network design parameters.

Keywords: District heating systems, multiple sources, storage systems, ring network configuration, automated district heating planning tool

Thomas Licklederer is a research associate at the Technical University of Munich. His current work focuses on the technical implementation and control of bidirectional heat networks based on prosumers. His research interests are modelling, optimization, and optimal control of smart energy systems.

A field-level control approach for bidirectional heat transfer stations in prosumer-based thermal networks: simulation and experimental evaluation

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Bidirectional heat transfer stations are an essential element to enable prosumer behavior in thermal networks as a part of smart energy systems. Previous research focuses on the operation of these transfer stations in networks where the thermohydraulic system state is dominated by central plants and thus transfer stations hardly influence each other. However, this is significantly different in thermal networks with a focus on the flexible energy exchange between peer prosumers. In former studies we proposed suitable network and substations designs and have shown that distributed actuators in the substations mutually influence each other. Further, it was shown that the overall thermohydraulic state is quite sensitive to the control of the distributed actuators and characterized by changing flow directions and velocities. This imposes new challenges for the network control and leads to the need of new control strategies for bidirectional transfer stations that meet the requirements of flexible prosumer energy exchange.

In our paper, we present and evaluate a field-level control approach for pumps and valves of bidirectional heat transfer stations in prosumer-based heat networks. The control approach is based on PID controllers for the primary and secondary side of each substation. Weighted error-functions consider heat transfer setpoints and temperature objectives at the same time, thus relaxing the control problem. The heat transfer setpoints can act as an interface to higher layers, such as a district energy management system or local market. Restrictions like desired feed-in or extraction temperatures are considered via the temperature objectives.

The proposed control approach is analyzed and evaluated using simulations and experiments. Modelica simulations are used to investigate the performance of the control approach in different scenarios with up to five prosumers. For experimental investigations we use a testbed comprising two prosumer building emulators that are connected by a thermal network and two prototype bidirectional heat transfer stations. With this setup the behavior of the prototypes is characterized, and the performance of the proposed control approach is evaluated in interaction with real hardware.

Keywords: district heating, prosumer, bidirectional, heat transfer station, control, heat network, smart thermal grid, substation, PID, simulation, modelica, experiment, laboratory, characterization, pump

Rasmus Magni Johannsen is a PhD fellow in the Sustainable Energy Planning Research group at Aalborg University, working with integrated energy system modelling on both a national and regional level and the development of holistic energy system scenarios.

Municipal energy system modelling – a practical comparison of optimisation and simulation approaches

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Energy system scenarios are increasingly included as part of energy planning on all scales, from the national scenarios to regional or municipal scenarios, and even at an urban scale. The use of scenarios for national energy planning is a well-established practice, and several relevant tools and models exist for conducting such analyses. Municipal energy system modelling is however an area of increasing interest from both energy practitioners and modellers and is becoming an important part of strategic energy planning.

Energy system modelling approaches can generally be divided into simulation-based and optimisation-based approaches, with differing modelling characteristics and vastly different scenario design processes. Lund et al. compare these two modelling approaches, defining them as archetypes of energy system modelling, specifying that the defining characteristic is whether a model includes endogenous or exogenous investment optimisation. The comparison by Lund et al. is largely limited to a theoretical perspective and does not explore further distinctions of optimisation and simulation models beyond the two overarching archetypes.

This study compares different energy system modelling approaches in the context of municipal energy system scenarios. This extends previous work with an emphasis on tool reviews, but limited attention to the underlying modelling approach applied, and the process established for developing future scenarios. This topic extends beyond individual tools, as it is predominantly a process guided by the modeller and the scenario design procedure. In this study we first conduct a review of existing modelling and scenario design methodologies, extending the concept of simulation and optimisation models to include sub-categories of the two archetypes. Based on a municipal case study, the impact of applying a proposed stepwise simulation approach relative to an established multi-objective optimisation approach is assessed to determine how the two distinctively different approaches to scenario design and modelling arrive at future scenarios. From this comparison, we derive guidelines for developing future energy system scenarios in a

municipal context, relevant for both municipal energy planning practitioners and energy system modellers.

Keywords: Municipal energy system scenarios, EnergyPLAN, EPLANopt, Simulation, Optimisation

Aadit is a research associate and PhD candidate at the Energy Economics Group (EEG) with focus on strategic heating and cooling planning. He has a master's degree in Energy and Environmental Management from the University of Flensburg.

Validation approaches under GDPR constraints for bottom-up building stock energy data: Case Vienna

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The "Spatial Energy Planning" project, funded in the frame of the Austrian Energy Model Region "Green-Energy-Lab", provides a detailed structured methodology for developing high granularity datasets focusing on heating transition. The methodology subjects input datasets from sources such as building energy performance certification, heating database, local district heating networks and statistical data through a series of spatial and statistical filtering and processing. The approach results in detailed building stock information on the spatial distribution, physical and energy properties, the end-use, and energy demand. However, options for validating the novel approach are limited due to the General Data Protection Regulation (GDPR) restrictions. Hence, in this paper, we developed a methodology and structure to validate the current outputs, with potential for application for datasets generated for other regions.

The validation of the datasets was conducted on two levels. First, the allocation of the building's geospatial attributes was checked, followed by a series of cross-validation measures and plausibility checks. For output datasets of each of the modules of the methodology, the distribution and statistical measures of the buildings based on end-use, construction period, physical properties, and energy consumption were analyzed. This facilitated the identification of possible outliers and their cause. If outliers were identified as errors originating from the methodology, potential alterations were proposed. This iterative approach provided a measure for improving the final results. The majority of the outliers were narrowed down to originate from the input datasets, thus emphasizing the importance of quality data inventory setup. In the second step, a comparative validation approach was undertaken. The outputs were tallied with the reference data acquired from the local distribution grid operator (Wiener Netze) on an aggregated level due to restrictions imposed by GDPR. Nevertheless, this allowed the evaluation of the data against measured data, which provided a solid basis for validation. Further detailed

comparative analysis on energy-specific indicators would provide ground for conclusive validation of the methodology.

Keywords: GDPR, bottom-up, heating demand,cross-validation,plausibility checks, gross floor area, specific heat demand

Philipp Mascherbauer is a second-year PHD student and employee at the Energy Economics Group at TU Vienna. His primary focus lies in modeling the energy demand in residential buildings in Europe, specifically looking at the influence of prosumers growing share in this sector.

Validation of modeling smart energy management systems in reduced order models with building simulation models

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Heat pumps are an alternative solution to conventional gas heating systems, and the demand for them has increased by over 30% this year in Austria. At the same time, electricity prices rise and increasing volatile renewable production makes load shifting with heat pumps more attractive. Optimization algorithms are often used to determine when to shift loads with heat pumps. However, these optimizations are usually computationally expensive, so reduced-order models are popularly used. This paper will answer the question to what extent an optimization for a heat pump operated building based on a reduced-order model is suitable to minimize operation costs. We use two different models for the same buildings to answer this question. The first model calculates the heating demand based on a reduced-order model and optimizes heat pump operation, keeping the indoor temperature in between a specific bandwidth. The resulting indoor temperature is used as set temperature in a non-linear building simulation model. By comparing the results of the complex building simulation model with optimized set temperature from the reduced-order model to a reference scenario, we determine how effective the optimization was. The building thermodynamics are highly dependent on the building parameters like insulation and thermal mass and the heating system. Results will show to which extent the reduced-order model sufficiently predicts heating demand for different types of heating systems, in particular for conventional, high-temperature radiators and large surface heating systems or thermal building activation.

Keywords: heat pumps, building modeling, optimization, load shifting

Alessandro Mati is a PhD student currently enrolled at the DIEF Department of the University of Florence. His research interest is centred on the modelling of energy systems focusing on hydrogen potential for the decarbonisation of industry.

Assessment of paper industry decarbonization potential via hydrogen based technologies in a multi energy system scenario : a case study

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Right after electricity production, industry represents the most energy-intensive sector globally accounting for one-third of final energy consumption and one-quarter of the final emissions into the atmosphere. Given this scenario, it is clear that in order to meet long-term energy targets the contribution of the industrial sector is crucial. The pulp and paper industry in Italy is a vibrant manufacturing sector and plays an essential role in the country's economy, accounting for a total 10% of total EU production while consuming 23 TWh y-1 of final thermal energy. Nonetheless, its reliance on natural gas for 90% of its production makes it a big contributor in terms of CO2 emissions.
This study aims at investigating the potential for decarbonizing the sector's energy demand by switching to different and greener energy supply systems. The main focus of the work is the assessment and integration of Renewable Energy Sources (RES) with green hydrogen technologies interlinked in the broader spectrum, namely electrolyzer, storage systems and hydrogen conversion via Combined Heat and Power (CHP) systems such as gas turbines and fuel cells for stationary applications.
The case study focuses on a real papermill located in Tuscany whose current demand is met by a cogeneration system running on natural gas. Different options are evaluated emphasizing the interaction and synergies of multiple energy carriers and related technologies, with regard to self-consumption and optimal components design. First, the hourly energy demand of the paper mill in terms of electric and thermal energy is characterized, then based on this each option is analytically assessed from a technical and economic standpoint via an in-house developed tool able to model multi-energy systems.
Finally, the obtained outcomes are presented highlighting the best identified solutions both in terms of emission reduction potential and techno-economic feasibility in the framework of paper industry decarbonization.

Keywords: -Hydrogen technologies
-Combined heat and power systems
-Pulp and paper sector
-Decarbonization of industry
-Techno-economic analysis

He specialises in energy system analysis for highly renewable energy systems. Understanding the role of different technlogies and system level impacts. He is particularly interested in the city-scale energy transition, considering local participation and the balance with the national-scale.

Scenarios for a decarbonised Europe: What is the role of energy efficiency?

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This study presents scenarios for decarbonised energy systems for each EU27 country and the United Kingdom. The study helps clarify the role of the Energy Efficiency First Principle and what it means within a fully decarbonised energy system highlighting which energy efficiency measures are most appropriate. The scenarios consist of significant energy efficiency improvements in the transport, industry and building sectors. Energy efficiency is also increased by designing the supply-side with synergy producing technologies coupled with appropriate energy grids. For example district heating. The combined contribution of the demand and supply-side measures increases the efficiency of the energy system to significantly reduce overall economic costs and resource demands. Numerous combinations of demand-side energy efficiency improvements are possible and each combination has different implications for the supply-side performance of the energy system. Therefore a key element of the study was to assess all these demand-side energy efficiency combinations within the energy system. This demonstrated the extent of impact the energy efficiency measures had on the demand-side decisions and the overall system performance. The results demonstrate that when energy efficiency measures are only assessed at the sector level without understanding the system outcomes, non-optimal efficiency measures could be selected. For instance, in the industrial sector hydrogen could be used to reduce biomass demand, but at a full energy system level, this type of fuel does not lead to lower biomass demand. In saying this, all energy-reducing measures should be applied in the industrial and transport sectors, although not in the building sector. In conclusion, complex system assessments should be made a requirement when analysing demand-side energy efficiency measures. Preferably within a whole energy system analysis and including all energy sectors within an interconnected Smart Energy System. The study demonstrates that this energy system design is cost-effective and low resource demanding.

Keywords: Energy, Efficiency, Sector, System, Transport, Industry, Buildings

My research focuses on application of AI, Machine Learning, Optimization, Simulations and Mathematical Modelling in domains such as Energy and Transport. In particular, district heating energy networks, freight transport networks; Intelligent Transport Systems

Toward the application of Data Analytics for Fault Detection in District Heating Substations.

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The idea of how to automatically monitor, detect and predict faults in a DHS (District Heating Substations) by analyzing sensor data collected from substations, e.g., data collected with IMD (Individual Metering and Debiting) sensors, is important due to its potential to cut cost in DHS. Another reason is that advances in algorithms in the fields of machine learning and optimization (collectively referred to as data analytics) offer new opportunities to make decisions based on large amounts of sensor data. This potential, if properly exploited, can help decision makers operating DHS by reducing the time used for fault detection, and thereby reduce the eventual economic losses from such faults.

To be able to meet the EU energy requirements, problems on all levels of the energy chain, including DHSs at the municipal level as well as optimizing metering systems in individual apartments, need to be addressed. Data analytics has a potential to address several of the requirements given by the EU energy directive, but both methods and techniques need to be adapted to the domain to meet a performance standard acceptable in practice, e.g., scalability, stability, etc. All aspects of the data analysis activity must be considered, including the quality of the data available and the algorithms, techniques and processes employed during model construction, in order to produce models with consistently high performance.

The overall purpose of this study is to discuss the potential for predictive data analytics, in order to improve fault monitoring, detection and prediction activities. The presentation shall focus on anomaly detection and validation in large-scale high-dimensional district heating data. Other key lessons learned from a three-year Swedish research project focusing on fault detection in DHS shall presented.

Keywords: Anomaly, Heating, Fault, Validation, Substation, Machine Learning

He joined EQUA in 2019 and is responsible for program development, particularly the new IDA Distrcts application, and supervises selected research projects.

IDA Districts: a QGIS plugin for automated thermal model generation and dynamic district simulation

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Optimal design of Smart Energy Systems requires a holistic dynamical simulation model of the entire district under consideration, including not only energy conversion plants and distributions systems, but also (prosumer) buildings, and energy storage units. Consequently, EQUA has developed a GIS-based prototype for modelling and simulation of district energy systems that offers five main advantages compared to the state of the art: i) scalable district models for coupled simulation of energy plants, energy distribution and energy consumption are enabled; ii) IDA Districts (a QGIS plugin) has been developed for an easy to use pre-processing including a pipe routing algorithm and postprocessing; iii) automatic generation of dynamic simulation models for IDA Solver; iv) linked modeling of heating and cooling networks based on pipe bundle models, which is a collection of pipes with thermal resistances; and v) new load models are calibrated based on measurement data or detailed building simulations.

The prototype was tested in three case studies. The first case study presents a pre-processing example showing the model structure of a district heating and cooling network in IDA Districts as well as a demonstration of the novel pipe routing algorithm. Then a large-scale district is simulated in the second case study. The third case study shows findings from a cold network, in which a geothermal probe field supplies 87 customers with energy for heating and cooling. Substations (including heat pumps), network and energy plant are simulated simultaneously.

Keywords: dynamic district simulation, coupled simulation, IDA Districts, IDA ICE, QGIS, automated model generation

Martin Neumayer is currently an industrial researcher at the Institut für nachhaltige Energieversorgung in Rosenheim. After graduating from and being a researcher at Rosenheim Technical University of Applied Sciences in 2018, he investigated self-organizing systems at the University of Augsburg.

Fault and anomaly detection in district heating substations: A survey focused on methodology and data sets

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District heating (DH) systems are essential building blocks for affordable, low-carbon heat supply. Eliminating faults in district heating substations can increase the efficiency of the whole DH system, reduce waste of energy, and assure the security of supply. We argue that eliminating faults will gain further importance on the way towards 4th Gen DH. Modern machine learning algorithms offer a way to detect faults and anomalies. However, they require large, high-quality data sets.
Therefore, we conduct a structured review of literature on data-driven fault and anomaly detection specifically in DH substations. We focus on the used methodologies and data sets. After screening more than 100 articles, we identify and analyse 30 relevant articles published in scientific venues.
Our results show a rising number of publications in this area.
Most publications rely on techniques such as visualization, thresholds, comparison to reference groups or a regression model to detect anomalies. However, only 3 articles showcase the potential of neural networks. One reason could be the absence of suitable data sets: While real-world data is used in most articles, publicly available and labelled data sets are missing. Existing data sets typically have a temporal resolution of 1 hour, extend from at least 2 months up to several years, and cover from 1 up to several thousand substations. To deal with unlabelled data 10 articles use clustering, e.g., to organize substations or measurements, find reference groups for comparison or detect anomalous substations.
We further observe that many articles do not distinguish between faults, anomalies, and poor-performing substations, i.e., clear terminology is missing. Furthermore, potential gains through fault detection are often not discussed or quantified.

Our survey indicates research should focus on establishing publicly available datasets as benchmarks. The scientific community would especially benefit from data sets with a detailed description of the measured data, occurring faults, and their properties. Open data sets alongside established evaluation metrics allow for the comparison of different approaches and foster competition. Further, terminology regarding faults, anomalies, and poor-performing substations should be clarified.

Keywords: District Heating, District Heating Substation, Fault Detection, Literature Review, Data Set, Data Driven, Anomaly Detection, Machine Learning

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

Evaluating near-optimal scenarios with EnergyPLAN to support policy makers

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Energy system modellers usually identify the optimal system configuration and expansion of capacity based on an economic objective function, or in multi-objective optimisation, a combination of multiple objectives such as greenhouse gas emissions and total system cost. However, there could be political, socio-economic, or environmental reasons justifying a policymaker's selection of a solution that is slightly more costly or greenhouse gas polluting than the uniquely optimal solution. Solely focusing on the uniquely optimal solution disregards potentially diverse alternatives, which based on different evaluation metrics could even be preferable. In a response to this challenge, the evaluation of near-optimal solutions is gaining attention in the energy system modelling field as an extension of traditional multi-objective optimisation studies and as a way to bridge the gap between simulation and optimisation approaches.

In this study, we explore the near-optimal solutions, outline the diversity of near-optimal solutions, and evaluate the relevance of these solutions in the context of municipal energy planning. To do this, we develop a methodology to produce and evaluate near-optimal solutions with the use of EnergyPLAN software. This methodology is based on the following steps: i) application of the EPLANopt model to couple EnergyPLAN with a Multi-Objective Evolutionary Algorithm, ii) selection of the admissible range for near-optimality, iii) application of a set of indicators to the near-optimal solutions to estimate their impact on socio-economic and environmental aspects, iv) clustering analysis to understand the trends and common patterns of near-optimal solutions. The investigated socio-economic and environmental indicators include the self-sufficiency of the system (reliance on import of electricity and fuels), land use, particle emissions, local investment and employment opportunities, system flexibility, and resilience towards future price changes. The proposed methodology is applied to a municipal case to determine its potential as a tool to support local policymakers in evaluating energy system scenarios from a selection of optimal and near-optimal solutions.

Keywords: Near-optimal, Energy system modelling, Energy scenarios, Energy planning

He studied mechanical engineering with a focus on energy and process engineering at the TU Graz. Since 2018 he works at AEE INTEC in the field of large-scale and thermochemical TES technologies. 2020 he started his dissertation on numerical modeling and simulation of TES.

Novel modeling toolkit for optimized design and integration of large-scale underground hot-water thermal energy storages in future energy systems

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Large-scale underground hot-water tank and pit thermal energy storages have a high potential to massively increase the share of renewable energy in future local and district energy systems through seasonal as well as short-term storage of volatile renewable energy sources. Furthermore, these large-scale thermal energy storage (LTES) technologies can increase the overall energy system flexibility by providing peak load capacities for power grids (Power2Heat) and thus enable the coupling of the electricity and heating sectors. They are also potentially the cheapest way to store large amounts of heat due to economies of scale and can be attractively integrated into urban environments. However, to fully exploit the potential of LTES, a proper design and integration of the storages by comprehensive planning and tuning of all relevant system components by means of numerical simulations is required.

Yet, available LTES models for this purpose are limited, lack essential features, such as an adequate representation of the interaction with the surrounding soil, or do not provide the necessary flexibility in the modeling process. Consequently, our overall goal is a novel Modelica-based LTES modeling toolkit for a more flexible and efficient modeling, system and storage design process.

Due to the equation-based and object-oriented language approach, Modelica models inherently offer higher adaptability, extendability and reusability. This flexibility is further enhanced by the capabilities of the modeling toolkit, which should eventually offer a wide range of configuration and combination options, for instance in terms of geometries (e.g., cylindrical, conical or hybrid geometries), boundary conditions or level of detail, specifically tailored to the application.

LTES models for cylindrical and conical geometries have already been developed and the accuracy demonstrated by validation case studies with measurements of executed storages

(e.g., pit thermal energy storage in Dronninglund, Denmark) and cross-comparisons with other numerical models. Moreover, the applicability of the models was tested and shown in techno-economic analyses and parameter studies for optimized design on storage and system level.

Keywords: Large-Scale Underground Hot-water Thermal Energy Storage, System Simulation, Modelica, Model Development and Validation, Modeling Toolkit

Dr Revesz is Senior Research Fellow at LSBU, where he holds technical leadership roles in the area of decarbonisation. He works across a number of complex and ambitious energy projects related to energy efficiency, waste heat recovery, and district heating & cooling.

Heat decarbonisation opportunities in urban neighborhoods – Building retrofit and low carbon energy supply assessment

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In 2019 the UK became the first major economy to pass laws to reduce its greenhouse gas emissions to net zero by 2050. Meeting this ambitious target not only requires a shift in energy supply from fossil fuels to low carbon energy sources, but also a reduction in energy demand through the roll-out of energy efficiency improvements to existing buildings. The UK has some of the oldest and most inefficient housing stock in Western Europe and the building sector is responsible for approximately half of energy consumption. The present work has a strong focus on exploring energy efficiency measures that could be applied to existing housing stock, using the London Borough of Islington (LBI) as a case study. The applicability of those energy efficiency measures to a range of different building archetype prominent within LBI is discussed and evaluated. The paper also discusses the suitability of a range of low carbon heat supply options, including District Heating and Cooling (DHC), which could play a significant role in the Council's journey to net zero. The methodology implemented includes both qualitative and quantitative assessment of the opportunities and benefits, with a focus on applicability, cost, and carbon savings associated with retrofit and low carbon energy supply. The overall evaluation approach presented in the paper is applicable to other urban areas of the UK. It can thus significantly support local-level energy planning, helping Local Authorities better prepare for the transition to net zero, reduce overall costs, and seize local opportunities.

Keywords: Heating, Retrofit, Urban, Planning

Mr. Roth is graduate research fellow in the Energy Systems research group at the IMS. The research focus here is the application-oriented conceptual design and implementation of mathematical optimization environments for the design and operation of sector-coupled multimodal microgrids.

OPTIMAL COMPONENT DIMENSIONING AND OPERATIONAL OPTIMIZATION OF A MOBILE-HYBRID ENERGY SUPPLY SYSTEM WITH DEFINED SYSTEM TOPOLOGY USING MILP

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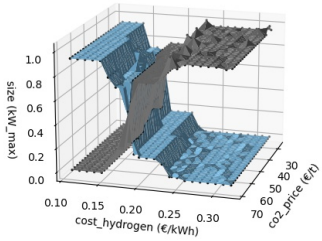
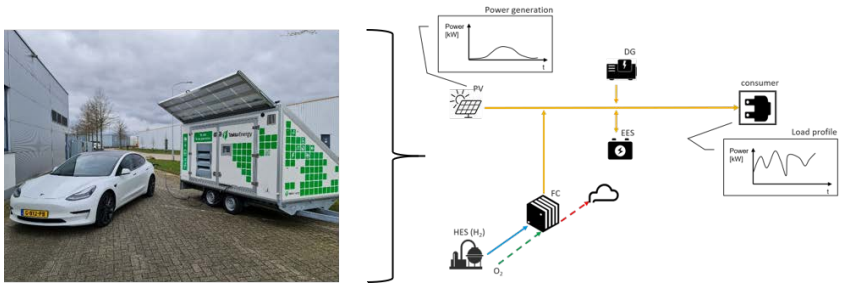
In the new Climate Protection Act 2021, the German government committed to being climate neutral as early as 2045. The ambitious legislation makes it all the more necessary to focus more strongly on previously largely untapped greenhouse gas saving potentials, such as the mobile supply of renewable electrical energy.
In this study an additional system component – a fuel cell (FC) – is added to a real system architecture for a mobile-hybrid energy supply system. The system works as follows: consumers are supplied with electrical energy by the overall mobile system, whereby the energy can potentially come from the photovoltaic modules (PV), the diesel generator (DG), the FC or the battery (EES). Exemplary consumers or customers of the service can be from road construction, festivals or other temporary events. Given exogenous PV production and load profiles, which can be generated by historical or forecast data, this study determines the cost-optimal sizing of the system components (FC, DG, and EES) while deriving the optimal operating strategy for the overall system. In addition to investment and operating costs, ecological costs are integrated, which primarily occur in the context of DG operation. The basis is the CO2 emissions price strategy applicable in Germany from 2021 onwards. The model is implemented in Python in the optimization environment Pyomo and solved by the Gurobi solver. The solver determines the cost-optimal values of the operational variables (e.g., optimal discharge power of the EES at each time step) and the global variables (e.g., optimal size of the FC over the entire optimization horizon). The exemplary optimization over 96 discrete time steps is performed for different combinations of H2 and CO2 price in order to derive not only the optimal variable values for the current price situation, but also for possible future price scenarios and to be able to make qualitative statements about the price sensitivity of individual variables.
The values of the global variables depend mainly on the relationship between demand and PV production, which is why the optimization is carried out for different operating days. The days

are classified according to the self-supply (SS) potential, which is determined by the ratio of demand and PV production.

Keywords: Microgrid, Fuell Cell, Hydrogen, Sizing, Scheduling, Mixed-Integer Linear Programming, Mobile Energy Supply, CO2-Pricing





The presenter is part of the Marie Curie Fellowship project- Zephyr under the framework of Horizon 2020, aimed towards efficient exploitation of onshore and urban wind energy resources. Her work is focused on optimising wind energy harnessing in urban area with focus on Savious wind turbine.

Wind energy potential assessment for the city of Nottingham using Weibull distribution estimation.

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With a sudden boom in industrialization over the past decade and increasing population, the demand for energy needs has gone up significantly around the globe. Considering the degrading effects of climate change, more emphasis is being added to the field of renewable energy. Wind energy, being a clean, sustainable, and a readily available source has proved to be very promising alternative to perishable sources of energy. This field is attracting a lot of research worldwide with main focus on cost effective methods and modified wind turbine designs to harness power.

The information related to the variation of wind is required in industry, especially by the wind turbine designers in order to optimize the design and reduce the related costs. It is also an important factor in locating the most suitable site for the turbine installation to get maximized efficiency. When the wind speeds are measured over the period of a year, a large fluctuation in the wind velocity is observed with mild and slow winds being more prevalent. The Weibull function thus helps to identify these wind patterns in terms of Weibull parameters for best use of this resource.

Wind measurements have been done over a period of one year at three different sites in Nottingham city, United Kingdom. The main aim of this paper is to analyze the wind pattern at the given locations using a 10 minutes averaged data. This will be achieved by preparing the Weibull distribution and comparing the Weibull parameters at these sites using different methodologies, namely:

- Graphical Method (GM),
- Method of Moments (MOM),
- Standard Deviation Method (STDM),
- Maximum Likelihood Method (MLM).

This analysis will enable us to identify areas in the city which are suitable for efficient operation of a wind turbine. The results obtained from different Weibull analysis techniques will then be compared by precisely ranking them with the help of different statistical tools.

Keywords: Weibull distribution, wind energy, wind data, numerical method, statistical tools

Robbe Salenbien is a senior researcher Energy Technology at the Flemish Institute for Technological Research. His work mainly focusses on the technical aspects of thermal systems and integration of those systems into the energy network. Recently, his efforts have been focused towards DHN design.

Showcasing the potential of non-linear topology optimization of District Heating Networks – District level and upwards

Robbe Salenbien, Flemish Institute for Technological Research VITO and EnergyVille. Yannick Wack, VITO and KU Leuven and EnergyVille, Tine Baelmans, KU Leuven and EnergyVille, Maarten Blommaert, KU Leuven and EnergyVille

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It is widely agreed upon that district heating can fulfill an important role in the transition towards a sustainable energy system. The technology has the power to merge energy carriers and infrastructure of different generations to cope with the high complexity of future energy systems. However, maximizing that potential depends critically on the optimality of the topology (lay-out). Whereas a large-scale rollout might be heavily influenced by capital investments, long-term adoption of the technology in turn depends more on the operational costs, the geographic circumstances and potential pre-existing infrastructure. Taking all of those aspects into account is a difficult task that requires automation, and even than often results in simplifications due to the sheer computational cost of induced by the large number of variables in the optimization problem. In this talk, we showcase the power and potential of a non-linear topology optimization approach (PathOpt) for large(r) district heating networks. The tool is demonstrated on a heat network project containing a few hundred heat consumers. The impact of specific project parameters (i.e. producer location, building heating system characteristics, …) on the overall optimal topology is shown, illustrating the importance of an integrated, automated approach.

Keywords: District heating and cooling, topology design, optimization, large scale

Malte's research focuses on life cycle assessment and energy systems. He is interested in the environmental impact related to electricity generation and consumption, and how electricity consumers can reduce this impact.

Life cycle oriented decision support for companies to reduce electricity-related greenhouse emissions

Malte Schäfer, Technische Universität Braunschweig

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The proposed method provides decision support for electricity consumers, primarily companies, that are interested in reducing electricity-related greenhouse gas emissions. It provides information on the current and future company emissions, on the emission reduction potential of mitigation measures, and on the degree to which they contribute to reaching company emission targets. The method combines an attributional and a consequential perspective, as to accurately best practices in emission accounting and in calculating avoided emissions.
The concept consists of six modules. In the goal and scope module (1), the user defines the location and time of interest, potential mitigation measures, the current company electricity load profile(s) and company emission targets (if available). In the mitigation option module (2), potential mitigation measures are categorized into one of seven categories (energy efficiency, temporal & spatial load shifting, on-site & off-site renewables, green electricity purchasing and site relocation) and the resulting load/generation profile and equipment life cycle emissions characterized. In the demand module (3), the user input from module 1 and the load/generation profile from module 2 are combined to calculate the grid load profile(s). Optionally in the demand module, load profile(s) is/are broken down into load profile(s) for sub-systems (e.g. machines, building HVAC). In the supply module (4), grid emission factors (EF) are calculated from an attributional (average EF) and a consequential perspective (marginal EF), for the present (based on historical data) and the future (based on scenarios), and for all relevant locations and time periods. In the impact assessment module (5), information from modules 1-4 is combined to calculate the current and future emissions for the status quo (without mitigation measures) and for implementing one or multiple mitigation measures. Finally, in the decision support module (6), the emission mitigation potential of all measures are ranked from both an attributional and a consequential perspective, and each measure's contribution to reaching the company's emission targets is calculated.
Considering the scope of the conference, the focus of the presentation will be on modules 2-4.

Keywords: Greenhouse gas emissions, electricity consumption, life cycle emissions, decision support, integrated method, emission factors

Shubham works in the field of rotor aerodynamics and aeroacoustics. For his PhD, he is working on aerodynamics and aeroacoustics of small vertical axis wind turbines for the urban environment. Previously in MSc, he has worked on propeller aerodynamics and aeroacoustics for Urban Air Mobility.

Feasibility study of different vertical axis wind turbines for wind conditions in the city of Nottingham

Shubham, Nottingham Trent University; Kevin Naik, Nottingham Trent University; Shivangi Sachar, IMP-PAN; Anton Ianakiev, Nottingham Trent University; Piotr Doerffer, IMP-PAN

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There has been an increasing push for the cities to go carbon-neutral, which has brought the focus on small-scale urban wind turbines. For a successful operation of such wind turbines, it is imperative to do a wind resource assessment of the city and predict the performance of different wind turbines in the available wind resources. Wind conditions in urban areas are more chaotic and turbulent in nature than in rural areas. Previous studies have shown that vertical axis wind turbines (VAWT) perform better than horizontal axis wind turbines (HAWT) in the former conditions. Due to a wide 3D design space in a VAWT, there is a lot of flexibility in the choice of design parameters. The aim of the current study is to study the feasibility of several wind turbines in a city by comparing their predicted power performance. The city of Nottingham in UK is chosen as the benchmark city.

The wind resources are obtained from weather stations located within the city. Two small VAWTs are investigated initially by using their publicly available power performance data and predicting the power output for the wind speeds obtained within the city. First VAWT is a helical-bladed TURBY from TU Delft which is having 3 blades. Second VAWT is another helical-bladed Quiet Revolution QR6 which is also having 3 blades. Initial investigations show that for a period of 1 year, average power generated by QR6 is 33.6 kW and by TURBY is 0.84 kW. Power production is fairly uniform throughout different seasons, contrary to solar PV panels which faces a drop during winters.

In the future, more VAWTs will be investigated including both Savonius and Darrieus design, single and multi-segment design, and full 3D design space of the VAWT will be explored by doing a power performance analysis using QBLADE software. This will help to make an informed choice of the best suitable value of the design variables to increase the levels of power output. The study also looks at using more than one wind turbine in a cluster, to leverage the increase in power production. As a result, a methodology will be developed for the selection of a wind

turbine based on local wind resources which can be replicated in any other city. This will be documented as a flowchart as a final outcome of this study.

Keywords: vertical axis wind turbine, darrieus, savonius, urban environment, performance, power, Nottingham

Peter Sorknæs is part of the Sustainable Energy Planning Research Group at Aalborg University, where he works with energy markets and hourly cross-sectoral energy system modelling of energy systems of different geographical scales with a focus on the heating sector.

The benefits of 4th generation district heating and energy efficient datacentres

Peter Sorknæs, Aalborg University. Steffen Nielsen, Aalborg University. Brian Vad Mathiesen, Aalborg University. Henrik Lund, Aalborg University. Diana Carolina Moreno Saltos, Aalborg University. Jakob Zinck Thellufsen, Aalborg University.

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This paper identifies the systems benefits of transitioning the district heating infrastructure from the current 3rd generation district heating (3GDH) to 4th generation district heating (4GDH) systems with lower grid temperatures and more integration with other energy sectors. Previous papers have investigated the effect of going from 3GDH to 4GDH on a local perspective or made a simplified national assessment. In this paper it is investigated how this transition affect the energy system on a national level, where geographical information system (GIS) analyses are used to identify effects on the grid, both in terms of pipe sizes, losses, and costs on a national scale. The results of the GIS analyses are then used in a future national climate neutral energy system scenario to estimate both the costs and energy system effects. This national scenario is simulated hourly including all energy sectors. Moreover, the paper identifies the parallel benefits of the implementation of high efficiency cooling solutions in datacentres, which could raise the temperature outlet of excess heat from current 20-25°C to 60°C. The analyses include effects on heat sources, such as geothermal energy and industrial excess heat, as well as the effect on the cost and losses in the district heating grid. On the case of Denmark, it is found that the system benefits of such to technological developments are substantial. Thus, the transitioning from 3GDH to 4GDH decrease the systems cost by 193-220 M EUR/year and increasing the temperature outlet of datacentres excess heat has a value for the system as high as 52 M EUR/year for with 4GDH and 59 M EUR/year with 3GDH.

Keywords: District Heating, datacentres, Energy system analyses, EnergyPLAN

After completing his studies at RWTH Aachen, Jan Stock started as a research associate at Forschungszentrum Jülich. His field of research is the transformation of existing district heating systems with a focus on lowering supply temperatures and the integration of sustainable heat sources.

Modelling of an Existing District Heating Network at Different Supply Temperatures with a New Integrated Waste Heat Source

Jan Stock, Forschungszentrum Jülich, Institute of Energy and Climate Research, Energy Systems Engineering (IEK-10); Felix Arjuna, Forschungszentrum Jülich, Institute of Energy and Climate Research, Energy Systems Engineering (IEK-10); André Xhonneux, Forschungszentrum Jülich, Institute of Energy and Climate Research, Energy Systems Engineering (IEK-10); Dirk Müller, Forschungszentrum Jülich, Institute of Energy and Climate Research, Energy Systems Engineering (IEK-10)/RWTH Aachen University, E.ON Energy Research Center, Institute for Energy Efficient Buildings and Indoor Climate

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A promising way to make use of waste heat sources is to distribute the heat to nearby buildings via district heating systems to cover the heat demands of the buildings. The integration of a waste heat source into an existing district heating system has to be studied in advance in order to avoid difficulties during network operation and to guarantee the required supply of heat to all connected buildings. The integration possibilities mainly depend on the network topology or rather on the geographical location of the additional heat source and the installed pipes in this area.

The situation of implementing a new waste heat source into an existing district heating system arises at the Forschungszentrum Jülich, Germany, as a new supercomputer on the campus emits waste heat at a low-temperature level of around 44°C. To make sensible use of the generated heat, its usage in the high-temperature district heating system of the campus, which supplies heat to the campus buildings at supply temperatures of 95-132°C, is examined.

In this case, the temperature level of the waste heat is centrally upgraded by a heat pump. In this work, we focus on the operational behaviour of the district heating network and study the influence of the additional integrated heat source on the network conditions. Therefore, we extend the existing district heating simulation model in Modelica to investigate the district heating operation with multiple heat sources.

We test two different control strategies of the additional integrated heat source to investigate their influences on network operating conditions. With the first control strategy, the waste heat source supplies a constant amount of heat, while with the second control strategy, a constant share of the total heat demand is supplied by the waste heat source. In addition, we also

simulate different supply temperatures to increase the operation efficiency and to study the impact of lower temperatures on network operation.

Keywords: District Heating, Modelling, Multiple Heat Sources, Low-Temperature

Business developer at the utility company Bornholms Energi og Forsyning

Flexibility Heat Grid Bornholm

Julius Kofoed and Torben Jørgensen, Bornholms Energi og Forsyning
Henrik Stærmose, NeoGrid Technologies
Emil Mahler Larsen, Utiligize

Henrik Stærmose (presenter)

The project investigates the potential of a fully flexible district heating network with participation of up to 65 household in the small village of Listed, Bornholm. The project runs in 2022.

The purpose of the project is to reduce fuel consumption, energy for pumping and heat loss. Targets:

- 10% increase in household's energy efficiency
- 20% decrease in heat loss from the grid
- 6% increase in heat production efficiency

All effects will contribute to reduced CO2 emissions.

The project includes the following demos/deliverables:

- Smart control of heating and hot water tanks in the households to enable flexibility and savings
- Optimized asset management tool, based on data from households and the heating system
- Data driven and automated detection of defects in the consumer's heating installation
- A simulation model to predict future capacity needs and effects from changes in the grid and/or consumption patterns
- Short term heat demand forecast (24 hours/1 week)
- Business case assessment from the consumer side as well as the district heating company perspective
- Evaluation of the consumer engagement and how to maximize consumer's value in future development projects

Project partners:

- Bornholms Energi og Forsyning, Technical University of Denmark, NeoGrid Technologies and Utiligize.

Find more information regarding Flexibility Heat Grid Bornholm (in Danish) on www.beof.dk/listed.

Keywords: District heating, datadriven consumption forecast, asset management, flexibility, living lab, efficient heat production, optimization at consumer site, heat loss reduction, Test Island Bornholm

Jakob Zinck Thellufsen is an Associate Professor in Energy Systems Analysis at Aalborg University, where he works with the development of energy systems analysis tools to link the concept of Smart Energy Systems to the discussion of energy transmission across countries.

From energy modelling to energy planning – the consequence of different types of system analysis

Jakob Zinck Thellufsen, Aalborg University

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In the transition towards renewable and decarbonized energy systems both locally, nationally and internationally, energy system analysis plays a bigger and bigger role. Energy system analysis can provide crucial insights in terms of how for instance much renewable capacity should be built, how different supply and demand sectors can be transitioned to support the renewable energy system and how much the transition costs. By conducting system analysis, the objective is often to identify the most cost-efficient transition towards decarbonization targets, but the models and tools have a hard time linking the energy system analysis to the energy planning also required to ensure the renewable energy transition.
This study therefore investigates a number of renewable energy transition scenarios from different modelling platforms, and discuss how carrying them out might impact challenges in the energy planning sphere of the renewable energy transition. Concretely, cases from Greece, the Nordics and Europe are analyzed. The results will show an analytical approach, where concrete design steps are taken to identify a smart energy solution for the energy system, this approach is compared to an optimization modeling approach that identifies the most cost-efficient solution under the given parameters of the analysis. The concrete differences in the resulting system design will be shown, and the impacts of changing assumptions in each modelling method will be highlighted, to show the impact it might have on energy planning processes.

Keywords: EnergyPLAN, energy system analysis, energy planning, smart energy systems

Anna Vannahme obtained her M.Sc. degree from the TU Munich. Her research focuses 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.

Central and decentral operation strategies to optimize existing district heating networks

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In the 1990s and 2000s, biogas cogeneration plants were built in rural Germany. The heat extracted from biogas cogeneration was often seen as a costless supplement to electricity generation. Since the focus was not on heat utilization, local district heating networks (DHNs) were built in areas with low heat demand density. With the ending of the Renewable Energies Act (EEG) subsidy after 20 years of CHP operation, the focus is now shifting to the efficient use of heat. Therefore, this study will help DHN operators to continue operating their DHNs more economically.

This paper presents the study of optimization measures on two DHNs using a simulation model written in Matlab / Simulink CARNOT. The final energy savings and the payback time for the implementation of the optimization measures were calculated. Two optimization measures that were investigated are:

1. The thermostatic controller of the DH substation was replaced by an electronic one. With a thermostatically controlled valve, there was also a small volume flow at the consumers substation when there was no consumption. This led to unnecessary circulation in the DHN. The electronically controlled valves close completely during periods without demand. This saves DHN losses and pumping energy, especially in summer when there is only a demand for domestic hot water.
2. Leoni (2018) presented a new intermittent operation strategy in which the DHN was filled with colder water during periods when consumers were supplied in a decentralized manner. The operation strategy was not investigated in more detail by Leoni (2018) as the setup is complex, but the payback period was found to be 12 years and the final thermal energy savings were 12 %. Since the DHN losses in the case study of the current project are significantly higher than in the one considered by Leoni, it was useful to examine the operating strategy in more detail.

It can be concluded that electronically controlled valves in the DH substations pay off in the medium term for heat production costs of 60 €/MWh. The intermittent operation strategy is cost-effective under certain boundary conditions.

References

Leoni, P., 2018. Projekt heat_portfolio (FFG-Nr. 848849) Deliverables D4.1 und D7.1. AUSTRIAN INSTITUTE OF TECHNOLOGY. Accessed 30 May 2020.

Keywords: central / decentral operation strategies, local district heating networks, optimization measures, district heating substation, system simulation, improving energy efficiency, low-investment measures

She works at the August-Wilhelm Scheer Institut, a private non-profit digitization research institute. She focuses on Smart Energy projects, helping to realize the energy grid of the foture by means of digitization.

The impact of increased information content on electricity load forecasting

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Electricity load forecasting of private households usually aims at predicting the household's total load by applying artificial intelligence methods to data measured at the household's grid connection point. This is a challenging task, as the parameters of interest are influenced by climate, seasonal and human factors. With the rising number of implemented digital metering systems, future data promises to not only contain the total load, but have an increased granularity, even covering the load of single household devices. This analysis investigates to which extent the knowledge of the per-device load will improve the forecast quality by training an artificial neural network (ANN) on the data measured at the grid connection point and comparing its results to the output of the same ANN trained on high-granularity data containing the load of every electricity load in the household. A dataset of 200 households simulated by the ProfileLoadGenerator tool serves as the basis of the analysis.

Keywords: load forecasting, private households, electricity load, ANN, granularity, variety

Yannick Wack is a PhD researcher of KU Leuven/Vito. His work focuses on developing optimization strategies for the optimal topology (layout) of next-generation District Heating Networks that account for the complex physical behavior of large-scale, low-temperature, multi-producer networks.

Approaches to non-linear topology optimization of District Heating Networks – A benchmark

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The optimal design of the topology (lay-out) of next generation District Heating Networks is a challenging problem. The increased physical complexity of low-temperature networks with multiple heat producers can be accounted for in the design by solving a mathematical optimization problem that incorporates fully-fledged non-linear heat transport models. Different successful attempts to solve this topology optimization problem for heat networks have been made in the past, both by using combinatorial optimization methods and, more recently, by using penalized adjoint methods. This penalized adjoint method was able to optimize heat networks of 160 consumers. In this talk, we present a benchmark of both approaches that compares the computational time needed to optimize district heating networks of increasing size. Here, the limitations of non-linear combinatorial approaches to find the optimal topology of large-scale District Heating Networks are discussed. The computational cost of the penalized adjoint method was found to scale below quadratic while the combinatorial approach scales exponentially, impeding networks beyond 165 consumers. In addition, the influence of different initialization strategies on the found optimal network topology were investigated. It is found that the initialization has an important impact on the quality of the found local optima for both combinatorial and adjoint optimization approaches, as soon as one moves away from simple one-producer cases.

Keywords: District Heating, optimal topology, optimal design, non-linear optimization, benchmark

Daniel Zinsmeister is a research associate at Technical University of Munich (TUM). After completing his degree in mechanical engineering, he worked at AUDI AG, before returning to TUM in 2018. His focus is constructing the CoSES laboratory and integrating prosumer into district heating grids.

A prosumer-based sector-coupled district heating and cooling laboratory architecture

Daniel Zinsmeister, Technical University of Munich;
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For a cost-effective energy transition, it is useful to couple the electricity sector with other sectors to evolve into a smart energy system. To exploit synergies between the electricity and thermal sector, new designs for district heating and cooling systems and their interaction with the electric system are required. These new designs are evaluated mostly with simulation models of varying level of detail. In order to analyze these systems in a more realistic setting, a laboratory environment was created at the research Center for Combined Smart Energy Systems (CoSES) at the Technical University of Munich (TUM). The laboratory allows to analyze the interaction between the electric distribution grid and district heating and cooling systems, test control concepts and generate data to validate simulation models.
This paper describes the design of the district heating and cooling environment of the CoSES laboratory. The main novelty of the implemented laboratory design is the integration of five thermal prosumers, connected by a bidirectional district heating and cooling grid. Each prosumer is equipped with heat and cold generators, thermal storages and emulated heat and cold consumption. The prosumers are connected to the thermal grid by a bidirectional heat and cold transfer station. The distance, dynamics and thermal losses of the district heating and cooling grid are emulated according to experiment requirements. The modular design of the laboratory allows it to be adaptable and expandable and can therefore be used for a wide range of experiments. The capabilities are demonstrated in a case study with thermal prosumers, which are managed by a central optimization.
This paper aims to foster collaboration with other researchers and to test new control designs. In this way, new approaches can be pre-qualified in a real-world environment without compromising user comfort, before being field tested or brought to market. In addition, the description of the laboratory can serve as a template for other district heating and cooling laboratories.

Keywords: district heating, district cooling, decentralized feed-in, prosumer, sector coupling, smart energy system

Kamil Kwiatkowski achieved PhD in fluid mechanics at Faculty of Physics University of Warsaw. He worked on biomass gasification and syngas combustion. Since 2018 in Euros Energy - a Polish manufacturer of heat pumps and designer of energy systems. Since 2021 - Director for Research Projects.

Heat pumps with triple heat storage levels for district heating system with 90 % of energy from renewable sources – a feasibility study with TRNSYS.

Kamil Kwiatkowski, Marcin Bugaj, Jakub Garbacik, Tomasz Walczak, Euros Energy Ltd

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The new heat pumps plant was designed to cover the heat demand for the modernised part of the district heating network in northeast Poland. The design power is 2 MW and the maximum operating temperature is 80°C.

The system uses heat pumps, to which electricity is supplied from local PV and PVT installations and, in small amounts, from the national power grid. Heat pumps cooperate with air heat exchangers and with the triple heat storage systems: two seasonal and one short-term buffer.

The first store is a seasonal low-temperature borehole thermal energy store (BTES), which consists of around 300 vertical heat exchangers with a length of 99 m with working temperatures in the range of 5°C - 15°C. This BTES is loaded over the summer with heat produced by heat pumps, for which the lower heat source is only the air heat exchanger, and heat from PVT hybrid collectors.

The second store is a seasonal, high-temperature Pit Thermal Energy Storage PTES, an insulated ground pool with a capacity of 15,000 m3 and operation temperature from 7°C to 70°C. To increase the overall SPF of the system the PTES is used only as a lower source for the heat pumps during the winter when the electricity production from PV and PVT is low.

The short-term heating network buffer is a water tank with a volume of 100 m3 and a temperature range of operation in the range of 60°C - 85°C. It maximizes the self-consumption of electricity produced locally in PV panels and PVT collectors.

Using BTES and PTES with different storage temperatures increases the efficiency of heat pumps and allows their compressors to operate on the entire range of working envelopes, also during the winter peak demand.

The whole system is modelled in TRNSYS 18, using appropriate components and local geological and weather conditions from northeast Poland. Time-resolution is 10 minutes. The final set of simulations covers reference results for the typical year and the results of the multidimensional sensitivity study.

The results reveal that the share of RES in the energy balance is 90.7% for the typical scenario and close to 90% for the vast majority of considered cases. Moreover, this indicator can be increased even further when electricity storage is used.

Keywords: heat pump, BTES, PTES

Richard van Leeuwen is professor Sustainable Energy Systems at Saxion University of Applied Sciences, the Netherlands. His research group focusses on renewable energy system integration, applied smart grids research, heating systems, energy storage systems, bio-energy and nutrient recycling.

Business case scenario analysis for hydrogen conversion, storage and consumption within energy hubs

Richard van Leeuwen, Annelies Boerman, Saxion University of Applied Sciences, the Netherlands

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Recently, smart energy hubs with hydrogen conversion and storage receive increased attention in the Netherlands. The hydrogen is to be used for vehicle filling stations, industrial processes and heating. During the energy planning phase, the proper sizing of capacities for renewable energy generation, hydrogen conversion and storage for the energy hub and achieving targets for security of hydrogen supply are important aspects of business case analyses. Scenario analysis is part of this but it often requires much time to evaluate scenarios, due to the difficulty of aquiring relevant data and the lack of easy-to-use models.

To overcome the difficulties with modelling, the available types of models are investigated and an algorithmic modelling method is developed and worked out in Microsoft Excel. Model validation is done by analysing internal energy balances and effects on results by inserting extreme values. We show results for a case study which has renewable energy input from solar PV and for which the possibility to import electricity is limited by two price boundaries. We demonstrate the use of the model for scenario analysis. As results of the scenario analysis, we show the relation between hydrogen electrolyser and storage capacities and the price boundaries on hydrogen price and security of supply.

The model is made available open-source. Future work is proposed in the direction of application of the model towards other project cases and comparison of results with other available modelling tools and practical data when this becomes available.

Keywords: renewable energy systems, energy planning, system integration, energy hubs, hydrogen conversion, business case analysis, energy modelling

He is a PhD student in Renewable Energy Community simulation at the University of Florence. Bachelor's degree in statistics and Master's degree in energy engineering. He has expereince in using python for energy system modeling and load forecasting.

Renewable Energy Communities: techno-economic assessment focusing on heat pump load shifting.

Mattia Pasqui, Pietro Lubello, Guglielmo Vaccaro, Luca Socci, Adriano Milazzo, Carlo Carcasci.

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Based on European Directive, the Italian Government has recently published the technical rules for access to the service for the valorizations and incentivization of shared electricity. These rules define the Renewable Energy Communities (REC) which are springing up all over Italy, so it is necessary to study these phenomena to make energy sharing as efficient as possible.
This study aim is to assess the role of heat pumps inside a REC and the possibility to shift the electric load of these technologies to increase collective self-consumption. First, the benefits that REC stakeholders gain from electrification of the heating, cooling and domestic hot water will be quantified. Second, different methodologies for the switching on time of heat pumps will be analyzed. Different cases are considered where heat pumps are owned by individual prosumers or consumers or where they are owned by a third-party company operating the REC. The analyses are related to a real REC in the city of Florence, which is in the process of being set up and does not yet have heat pumps. The methodology used can be divided into three parts: first, the characterization of hourly energy demand curves including appliances and heat pump demand. The latter is calculated based on buildings characteristics, habits of the inhabitants and the climate; and can be shifted considering the thermal inertia. These curves were then used as input for Multi Energy System Simulator (MESS), which solves every hour the energy flows of solar panels, batteries and loads to calculate each dwellings energy balance and REC collective-self-consumption. Finally, economic analyses can be carried out based on the energy balances obtained and different simulations can be compared.

Keywords: Renewable energy community, load shifting, heat pump, collective self-consumption, self-consumption, load forecasting, energy systems, photovoltaic panels.

Thomas Riegler, M.Sc. is a research associate at AEE INTEC and works in the department of technology development in the thermal energy storage group. His main research fields at AEE INTEC are geotechnical engineering, civil engineering and management of large-scale thermal energy storage.

Structural challenges and innovative concepts for large-scale underground thermal energy storage

Thomas Riegler, AEE INTEC, Samuel Knabl, AEE INTEC, Wim van Helden, AEE INTEC, Michael Reisenbichler, AEE INTEC

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Large-scale hot-water underground tank (TTES) and pit (PTES) thermal energy storages integrated into district heating networks enable short-, mid-therm and seasonal storage of volatile energy sources (e.g. solar thermal, wind and PV), a flexible storage of waste heat as well as the coupling of the electricity and heating sectors through power-to-heat solutions. Due to their promising cost potentials in construction and operation, large-scale underground hot-water thermal energy storages will be a key technology for a system-based and cost effctive decarbonization of future district heating systems.

Based on the requirements of national and international district heating networks, TTES and PTES will be designed with storage volumes (storage medium water) up to the „million cubic meter scale“. Despite the high potential, however, there is a lack of feasible, affordable technologies and construction methods due to the challenging boundary conditions in Austria and Central Europe, as well as a lack of guidelines and standardization. For example, the urban integration of these structures requires minimal land use, utilization of the storage surface, and aesthetic integration into cityscapes and landscapes. In addition, high storage temperatures of up to 99°C and dynamic loads caused by storage operation have a challenging effect on materials (e.g. liner material) and components (e.g. wall systems).

The presentation focuses on two main aspects for a successful establishment of large-scale underground hot-water thermal energy storages in Austria. First, the different main components of such a storage are presented as well as their structural challenges which provides a basis for future concept developments as well as the construction design. Secondly, novel structural concepts which have been developed on the basis of the structural challenges are presented. Furthermore, the requirements for the development of novel material and component evaluation methods will be presented, which is seen as an essential step to increase the technology readiness level and ultimately allow an upscaling to real scale.

Keywords: Large-scale underground thermal energy storage, renewable energy

Prof. Vittorio Verda is Full Professor at the Energy Department of Politecnico di Torino. His research interests cover thermodynamics, heat transfer, district heating and thermal storage. He has collaborated on R&D projects financed both by governmental agencies, including EU, and industry.

Efficient Heat Pump integration in existing large district heating networks

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Existing district heating networks are often operating at higher temperatures that what is actually necessary, as thermal substations generally results as oversized. The adoption of higher temperature limits the integration of renewable energy sources as well as waste heat in the existing network. The main constraint on temperature reduction in such cases is represented by the circulating mass flow rate, which might create fluid dynamic bottlenecks. When large district heating networks are considered, such bottlenecks are typically located on the transport network, i.e. the pipeline connecting the thermal plants with the various areas of the town. In contrast such issue is not encountered in the distribution networks. In this context, the adoption of heat pumps can represent an interesting opportunity. The idea is to use heat pumps in order to make the distribution network as independent and flexible as possible. This goal can be reached by adopting a suitable integration scheme for large heat pumps, which can be effectively used for power-to-heat purpose. In this work the potential of smart integration scheme for the integration of heat pumps in existing DH is investigated. In order to consider a realistic application, a case study of an existing system currently operating at temperature over 100 °C is considered. The work is carried out considering the available data of a real case DH distribution network. The realistic opportunities to reduce the supply temperature are shown, also considering that the percentage contribution of the heat pump to the demand of the distribution network can be increased when the outdoor temperature increases. The significant benefits that can be obtained by the investigated solution are then presented and discussed.

Keywords: heat pumps, power-to-heat, supply temperature reduction, thermal networks, district heating renovation

Thilo Walser is Research Employee at Solites. His work focuses on the optimisation of complex energy supply concepts through dynamic system simulation, their design consultancy and evaluation. He worked on a number of national and international cooperation projects related to solar and sustainable thermal energy systems.

Technical and economical optimisation of district heating networks with decentralised buffer storage tanks

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District heating (DH) systems in rural areas often show lower heat densities compared to larger urban DH systems. Because of this, relative thermal losses of the rural DH networks are often higher and economy is worse compared to larger urban DH networks. To overcome this an approach with decentralised buffer storage tanks in consumer houses was investigated in the framework of the Horizon 2020 Project TEMPO - Temperature Optimisation for Low Temperature District Heating across Europe (GA 768936). As part of this work, a simulation study was conducted to elaborate the technical and economical optimisation potential of the concept.

Decentralised buffer tanks reduce the peak heat demands of single consumers and the entire DH network. This allows for smaller DH network pipe dimensions, leading to reduced thermal pipe losses and reduced DH network cost. On the other hand, buffer storage tanks increase both thermal losses and cost in the consumer house stations. House stations with decentralised buffer tanks furthermore show a different consumption profile compared to standard substations influencing the simultaneity behaviour of multiple consumers.

Results of the study show a reduction potential of house connection capacity rates for new standard single-family houses from todays approx. 30 kW down to theoretically 7.5 kW. New simultaneity factors could be derived for DH networks with decentralised buffer storage tanks. The new simultaneity factors allow DH network pipe designs taking into account the differing characteristics of the decentralised buffer tank approach.

A variation of 26% of yearly total thermal losses was found for the investigated configurations with double pipes in standard insulation. Cost savings for smaller DH network pipes are compensated partly by larger buffer tank volumes in the house stations. Besides, total cost figures are influenced by the varying thermal losses for different configurations. In sum the variation in total yearly cost for the investigated configurations with double pipes in standard insulation was calculated to 11%.

Keywords: District heating, DH, low heat density supply areas, decentralised buffer storage tanks, peak load reduction, simultaneity, technical and economical design optimisation

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Impact of international transportation options on cost of green e-hydrogen supply: Global cost of hydrogen and consequences for Germany and Finland

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Fossil fuels are the primary drivers of climate change. Moreover, they are concentrated in specific locations, while the majority of global population lives in countries with no or little resources. On the other hand, Renewable energy (RE) is widely available across the globe and with decreasing cost of solar PV and wind power, more people will get access to cheap electricity. Uptake of RE may enable production of RE-based e-hydrogen at any location, thus nations can meet their own hydrogen demand, and possibly even export to countries with area limit or high production cost.

This paper focuses on the feasibility of e-hydrogen imports to Germany and Finland from two case regions with high availability of RE, Chile and Morocco, in comparison to domestic supply. Cost of e-hydrogen production is estimated globally for the years 2020-2050 in 10-year steps. Nine different scenarios are considered: optimistic, main, and pessimistic with 5%, 7%, 9% WACC. Transport infrastructure has a crucial impact on economic feasibility of imports, thus shipping and pipeline routes are considered, including compression, liquefaction, terminals, ships, regasification, and storage.

Import costs that include the production and transport costs for the whole chain are presented and compared to the cost of local production of e-hydrogen in Germany and Finland. Preliminary results show that in 2050 e-hydrogen can be produced for 26.0 and 22.4 €/MWh,H2,LHV in Morocco and Chile, respectively, compared to 34.2 and 41.0 €/MWh,H2,LHV in Germany and Finland, respectively, given 7% WACC. Accounting for transport infrastructure leads to high import costs at 50 and 56 to Germany and 63 and 59 €/MWh,H2,LHV to Finland from Morocco and Chile, respectively.

Despite 25-45% cheaper RE in Morocco and Chile compared to Germany and Finland, the final import cost is 30-40% higher compared to locally produced e-hydrogen. It is possible that hydrogen may become the fuel that is mostly produced domestically and may be feasible for

import only in specific locations. International trade of could be beneficial for more dense fuels such as e-FTL and e-methanol. Benefits of local e-hydrogen production are lower dependence on imports, enhanced energy security, added jobs and contributions to the local economy.

Keywords: hydrogen transportation, hydrogen production, hydrogen infrastructure, e-hydrogen, renewable energy

Leif Gustavsson is a professor at Linnaeus University. His main field of research is systems analysis from a bottom-up perspective linked to sustainable development, especially building construction, energy efficiency, renewable energy, forestry and the interaction between these fields.

A sustainable replacement for diesel trucking: Comparing battery electric and biofuel trucks

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Heavy duty vehicles contribute significantly to climate change, and were responsible for 7% of total Swedish greenhouse gas emissions in 2020 (excluding land use and international transports), and 20% of total domestic transport emissions. Here we study medium- and heavy-duty cargo trucks powered by different energy pathways, comparing their biomass feedstock use, primary energy use, net CO2 emission, and cumulative radiative forcing. We consider the full lifecycle of the trucks, including manufacture and operation. We analyse battery electric trucks (BETs) powered by bioelectricity generated using woody biomass, in standalone and combined heat and power (CHP) plants, with and without CCS. We also consider the integration of bioelectricity and wind electricity. We analyse internal combustion trucks (ICTs) powered by fossil diesel fuel and by dimethyl-ether (DME) derived from woody biomass, with and without CCS. Electricity and DME are produced from forest harvest residue, and our system boundaries include all fossil and biogenic emissions from technical systems, and the avoided decay emission from harvest residue left in the forest. In a sensitivity analysis we consider the battery lifespan, the energy and carbon intensity of different battery chemistries, the technology level of the energy conversion systems, the source of biomass feedstock, and the biomass transport distance. We find that the pathways using electricity to power BETs have strongly lower climate impacts, compared to the liquid-fuelled ICT pathways using diesel and DME. The pathways using bioelectricity with CCS result in negative emissions leading to global cooling. The pathways using diesel and DME have substantial climate impact, even with CCS. These findings suggest that truck electrification may be a wise strategy for climate-adapted cargo transport, together with scaling up renewable electricity generation.

Keywords: cargo trucks, dimethyl-ether, battery electric vehicles, climate change, woody biomass, BECCS

Rasmus Lund is a project manager at PlanEnergi, working on project to plan for and implement smart and renewable energy systems with a focus on district heating. He has a background with a M.Sc. and a Ph.D in sustainable energy planning from Aalborg University.

Is storage needed in sector coupling?

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Renewable energy as wind and solar are fluctuating and its resource cannot be controlled and at the same time the demands for the energy services are ever present, are not in sync with the production and cannot easily be changed either. This fundamental problem can be handled in different ways, and historically it has been handled on the production side by dispatchable production capacity and eventually curtailment of excess production. This approach, however, is under pressure by environmental as well as economic considerations, and alternative strategies, like sector coupling, flexible demand, electrification and energy storage are brought into play. The present study focuses on the role of different promising energy storage systems in sector coupling application to increase the flexibility of it, and the potential of that strategy in an integrated energy system context. Different storage types and technologies will be analyzed and assessed on their effectiveness and efficiency in terms of primary energy supply and economic costs of energy supply and compared to each other and to a common reference case. The advanced energy system analysis tool EnergyPLAN will be used to perform the analyses based on existing national scale energy system models for 2050 with large scale integration of renewable energy as a reference. It is expected to conclude on the effectiveness and efficiency of different storage types in different contexts and make recommendations based on that.

Keywords: Energy storage, sector coupling, energy system analysis, EnergyPLAN,

Emanuela Marzi is a PhD student in Industrial Engineering at the University of Parma, Italy. Her research interests are related to the smart control and optimization of multi-energy systems, with particular focus on the integration of Power-to-X solutions in such systems.

Development of a smart controller for the integration of Power-to-Gas solutions in a multi-energy system: problem formulation and application

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The ambitious European objectives for the mitigation of global warming lead to the necessity to find alternative solutions to the current use of fossil fuels, in order to reduce the global greenhouse gas emissions. In this context, the shift from the use of fossil to renewable energy sources is seen as one of the most promising solutions, due to the limitless and clean energy supply these sources offer. However, there are lots of uncertainties on how to perform this transition, and this issue is at the forefront of current research. The exploitation of such sources has successful results in decarbonizing the power sector, however, the decarbonization of the so-called hard-to-abate sectors, namely those sectors which electrification is hard or impossible, presents several challenges. In addition, the intermittency nature of renewable energies must be balanced for electric grid stability purposes. The Power-to-X technology, namely the production of fuels from electricity, can help in this framework: indeed, it allows to produce fuels from renewable electricity, which can be used both for the decarbonization of the hard-to-abate sectors and as a long-term energy storage solution, allowing to store the surplus renewable energy and to balance the power grid. A smart energy system, however, which comprises such innovative solutions, requires intelligent management and control methods to optimize its operation. In this work, a predictive controller was developed, that optimizes a multi-energy system, in which sector coupling was obtained through the use of Power-to-Gas solution, i.e. the production of gaseous fuels from electricity. The controller uses a simplified model of the system, based on linear equations, and it was applied to an industrial case study with both electrical and thermal needs, coupled with renewable energy production. Thanks to the adoption of the predictive controller, with the Power-to-Gas system it was possible to balance the renewable energy production and to provide a seasonal storage for the periods in which the renewable production was low or absent.

Keywords: Smart energy system, power-to-gas, model predictive control, mixed-integer linear programming, multi-energy system.

His research fields are statistics database, scenario study, policy framework and business model of renewable energy in Japan. He took a degree as doctor of Engineering for Energy Conversion from Tokyo Institute of Technology in 1990.

Control and utilization of surplus electricity for the high share of variable renewable energy in Japan

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As a result of so rapid connection of variable renewable energy (VRE) to the grid, mainly solar power, in Japan, the Kyushu area has begun curtailment of VRE, and it is assumed that other areas will also begin curtailment near future. This paper analyzes the factors behind the curtailment of VRE based on supply and demand data from the TSO and evaluates the future outlook for surplus electricity in scenarios for high share of VRE, and considers how the power system should be controlled and how surplus electricity should be used for sector coupling.

Keywords: Variable Renewable Energy, Solar power, curtailment, sector coupling

He is Assistant Professor in Smart Energy Systems for the Built Environment. Alumnus of Sapienza University of Rome, from which he graduated Summa Cum Laude in Architectural and Building Engineering in 2011 and obtained his Ph.D. with Honors in Energy Saving and Distributed Microgeneration in 2015.

Power To Hydrogen for Energy Flexible Communities

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Energy flexibility is mentioned more and more as a strategy to make more efficient the energy supply both from the producers and distributors side and customers one. Flexibility solutions are those technologies that enable the use of such flexibility in terms of load shifting, peak clipping, adapted dynamically to infrastructures needs, energy market ones and, recently, users preferences. Such changes are crucial to increasing further the penetration of renewable energy especially in constrained contexts like the islands. Indeed, the weakness of the connection to the Power Grid, where present, compared to the strong variability of load profiles due to the touristic seasonality as well as the difficult updates of the infrastructures due to the landscaping constraints. The GIFT (Geographical Islands FlexibiliTy) project funded Horizon 2020 framework deals with these issues implementing into two demo-sites in Italy and Norway the innovative solutions. Among those technology, Power-To-Gas is used to provide flexibility at the building stock level. The Italian demo-site is Procida Island where a Reversible Solid Oxide Cell is installed to interact with the building energy loads and local PV production to provide flexibility to the Local Renewable Energy Community. This latter is composed by different kind of prosumers and the changes in final request of electricity to the Power Grid is actually the Flexibility created by them. Innovative Energy Management Systems handling the interaction of data and energy flows allowing the sustainability of new Business Models are integrated with the prosumers. For this purpose, the local green Hydrogen production and use is investigated and tested to evaluate its contribution to the Renewable Energy Community operation.

Keywords: P2G, Renewable Energy Community, Flexibility, Prosumers, Green Hydrogen.

He is working on energy system modeling with a focus on carbon neutral energy systems in Japan.

Renewable Energy Systems Considering Profitability of PtG and PtL - a Case Study of Japan

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Fuel synthesis, including Power to Gas (PtG) and Power to Liquid (PtL), are a key carbon capture and utilization (CCU) technology and a desirable solution for decarbonization in hard-to-abate sector. In addition, flexible operation of them in fluctuating renewable energy systems could contribute grid flexibility. Our research question is whether such an operation is economically feasible. To answer it, we apply break-even point analysis and a 100% renewable energy system model taking Japan as a case study. Our model takes into account sector coupling of electricity, transportation, and synthetic fuels, as well as interregional energy trading at hourly and prefectural resolution. In order to ensure the profitability of fuel synthesis, constraints regulating lower bound of the capacity factor are implemented. The break-even point analysis, which assumes future technology costs, is conducted to estimate the profitable capacity factor as a threshold. Three findings result from this study. First, hydrogen production with flexible operation is not feasible because the capacity factor of electrolyzer is below the profitability threshold in the absence of profitability constraints. Second, the role of fuel synthesis for grid flexibility is to follow off-peaks in fluctuating electricity generation and curtail operations. Fuel synthesis operation also follows the positive peak in the case without profitability constraints, however this role is substituted by storage technologies in the case with profitability constraints. Consequently, additional stationary batteries are installed and the system cost increases by 5%. These results indicate that energy system models that do not consider profitability may be infeasible from a business perspective and system costs may be underestimated, which is our third findings.

Keywords: Sector-coupled energy system, Optimization model, Break-even point analysis, Power to gas (PtG), Power to liquid (PtL), Profitability, Fuel synthesis

Matteo Pozzi, following a MSci in Physics and a DIploma in International Relations, started a career as Management Consultant in Italy and the UK. CEO and partner of Optit, providing Decision Support Systems based on analytics & AI to unlock operational efficiency, also serves as Vice-Chair of DHC+

Integrated Planning of Multi-Energy Systems (PlaMES): the Decision Support System and exploitation opportunities

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The Horizon 2020 PlaMES project, terminating in October 2022, has produced a Decision Support System designed to generate optimal scenarios of future energy systems at national and regional level finding the optimal balance between development of Renewable Energy Sources installation and investments on transmission/distribution infrastructure, targeting set emissions reductions while minimising overall system costs.
Future heat and electricity demand are analysed in conjunction with the adoption of renewables and full exploitation of "green supply" opportunities, employing a marked multi-energy approach that leverages on coupling technologies (power to heat, power to gas, heat pumps, CHP, …). Models manage a hourly granularity over a year-long horizon to take into account the complex dynamics of sector integration, seasonal behaviours and storage opportunities, within the constraints set by the user while configuring the scenario. District heating is considered in the model, managed as effective means to fulfil heat demand leveraging on a mix of technologies (e.g. HP, Thermal Storage etc.) to balance the overall energy system.
The project outcomes are the results of a joint effort that combines the expertise of the RWTH Aachen University, the Fraunhofer Institute, Optit srl and the University of Bologna, plus the Turkish Utility OEADS as demo site for the regional use case. The project had the ambition to resolve big data scenarios without significant compromises on details, facing significant modelling as well as computational and usability challenges, with interesting results.
Looking at the case of Germany, we intend to provide a quick overview and demo of the solution, highlighting the methodologies and models' underlying logics, showcasing a tool that is intended to support the analysis on decarbonisation and transition paths that most countries and national TSOs are currently designing, aiming at the challenging 2050 targets whilst searching for sustainable investment's strategies. Rules of engagement to initiate and carry on such analyses will be shared, to promote a full exploitation and valorisation of the project's

deliverables and multiply impacts at EU and global scale through replication and progressive sophistication of the value proposition.

Keywords: Energy Policy & Planning, Decision Support System, Operations Research in Energy, Decarbonization

Els is researcher on the field of energy & water at KWR Water. At the TU Delft, she has a position as external PhD student. She takes on a system perspective and conceptualizes the neighbourhood of the future, with energy and water supply, demand and storage and conversion techniques.

Heat utilization from hydrogen production – an example of local energy system integration

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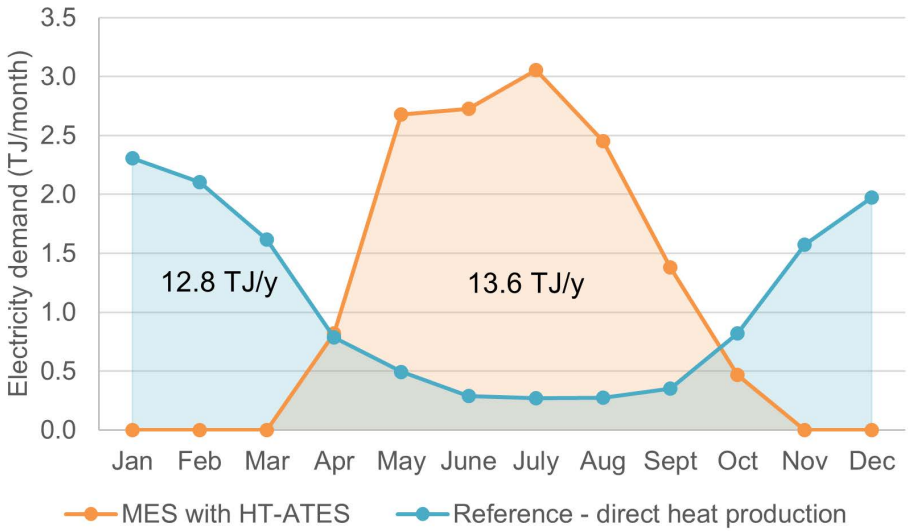
Our future energy system needs to be reliable, affordable and clean. To reach that goal, we have to make smart combinations wherever we can to create an integrated energy system that still matches energy supply and demand in both time and space. Green hydrogen production by water electrolysis with renewable electricity can play an important role in the future energy system. Hydrogen is a zero carbon energy carrier, that is able to transport and store renewable energy cost efficient and de-carbonize energy use in industry, transport and buildings. When hydrogen is produced at 80% efficiency (HHV), this means that the other 20% of the energy is converted to heat. Moreover, the heat production increases over time due to degradation of the stacks. In an electrolyser this heat is produced at a temperature of 60-80°C. Normally, this heat is dissipated by air coolers on top of the electrolyser containers, while it could increase the total system efficiency if this heat could be used. However, there is a lack of detailed system design and analysis for the utilization of waste heat from electrolysis.
In our study, we analyzed different designs for the utilization of electrolyser waste heat for a 2MWel electrolyser in Nieuwegein, the Netherlands. Redundancy is an important aspect of the design, to make sure the electrolyser can always be safely operated to produce hydrogen, regardless of the heat demand of the heat consumer. We investigated different use cases, such as local heat consumption at two different temperature levels, as well as a use case for a local district heating system for about 2000 households combined with seasonal heat storage. We performed a first order techno-economic analysis showing that the transport distance of heat is an important factor in determining the feasibility of waste heat utilization. The feasible

distance varies per use case, but in general should not exceed 2 km. For the district heating system, we show that the electrolyser waste heat can fulfill around 10% of the total heat demand of the neighborhood. Overall, we show that electrolyser waste heat can both from an environmental and economic point of view be a valuable addition to an local integrated energy system, and further enhance local system optimization.

Keywords: hydrogen, electrolyser heat, decentralized energy production, local system integration



Costanza Saletti is a researcher at the Department of Engineering and Architecture of the University of Parma, Italy. Her research interests are related to the simulation, optimization and smart control of integrated energy systems and district heating and cooling networks.

Implementation and testing of a multi-level smart control strategy for the integrated energy system of a hospital

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Integrated energy systems have recently gained a primary importance in the clean energy transition pathway. The combination of the electricity, heating and gas sectors pledges to improve the overall system efficiency and integration of renewables by exploiting the synergies among the energy vectors. Nevertheless, systems with several interacting energy conversion units and distribution networks are more complex and can be operated effectively only by means of novel digital and automation tools. In particular, real-time optimization tools based on Model Predictive Control (MPC) can lead integrated energy systems to a superior performance by automatically coordinating all interacting technologies. Despite the relevance of several simulation studies on the topic, however, it is significantly harder to have experimental demonstration of this superiority.

This work presents the real-world implementation of a novel smart control strategy for integrated energy systems, based on two coordinated MPC levels, which optimize the operation of all conversion units in the short and long term, respectively. This architecture gives the possibility to control the system in real-time while accounting for long-term features and constraints (e.g. incentives and seasonal storage).

After its development and evaluation in simulation environment, the strategy is actually implemented to control the integrated energy system of a real hospital in northern Italy. The system involves four energy vectors (i.e. heat, cold, electricity, steam), several conversion units (i.e. boilers, trigeneration plant, electric chillers and steam generators) and heating and cooling distribution loops. The MPC control strategy is run as a supervisory controller through a dedicated computer, which dynamically communicates the optimal set-points to the existing

Building Management System. In this way, the optimal control logic is easily actuated without having to alter the system configuration or low-level control.
The system has been monitored before and after the actuation of the MPC, in order to define the baseline operation and to verify the performance of the new strategy, respectively. The results from these first field tests are reported and compared.

Keywords: sector integration; district heating and cooling networks; smart energy systems; field tests; Model Predictive Control; long-term optimization; short-term optimization;

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IEA DHC Annex TS7: Industry-DHC Symbiosis: A systemic approach for highly integrated industrial and thermal energy systems

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The Annex aims to identify synergy effects and potentials that result from sector coupling of industry and thermal energy networks to accelerate their intensified use.
From an exergetic point of view, high-quality energy sources should only be used where a high temperature is necessary . Key therefore is the cascading use and exchange of energy between different sectors. Waste heat from industry can be a major contributor in the decarbonization of district heating networks and the supply of energy to urban areas. In a similar way, district heating can help to serve production processes with low temperature requirements and thus displace fossil energy from industrial energy systems. The supply of (process) cooling opens new possibilities for decentralized energy concepts. Thermal networks are thus an important platform for the mutual exchange of energy.
The Annex is intended to present the current state of the art, identify obstacles of implementation, highlight potential applications and provide recommendations. In doing so, the most diverse requirements of industries/processes are considered, and their possible potential is described. The following sub tasks are planned: Review of best-practice examples, Evaluation of promising integration options, Transformation strategies, and Future-proof business models.

Keywords: district heating, industrial waste heat, sector coupling, decarbonization

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Assessment of transport electrification and district cooling towards smart energy systems in hot climate countries

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Coupling mobility and heating and cooling sectors with electricity is one of the key steps towards smart energy systems. It allows cost-efficient integration of energy sources, particularly with high penetration of variable renewable energy sources. However, unlike district heating, studies on district cooling integration into the energy systems are rare, especially for the Global South with hot and humid climates. Therefore, in this study, we investigate the options for integrating electric vehicles and district cooling in the energy systems in hot climate countries. On the supply side, we use geographical potential and multi-criteria decision analysis results from relevant stakeholders to identify suitable renewable resources for the smart energy systems. On the demand side, we implement geographic demand distribution and energy efficiency. The impacts of sector coupling are assessed using EnergyPLAN by identifying several scenarios. We perform a sensitivity analysis using the costs of electric vehicles and carbon tax. For case studies, we choose Indonesia and Bangladesh. Both countries share similarities in the current status of the energy transition, demographics, climate, and other socio-economic parameters. The energy consumption in these countries has increased significantly during the last decade—transportation and electricity sectors have grown almost twice. These sectors rely heavily on local and imported fossil fuels, and the electricity sector experiences a significant rise in traditional cooling demand. We expect that the results of this study will help to realise the broader perspective of the smart energy systems in hot climate countries in terms of energy security and emission reduction. Critical issues, such as storage requirements and implementation pathways, have been discussed considering regional context, off-the-shelve technologies, and emerging renewable systems with the help of scenario analysis.

Keywords: RES integration, EnergyPLAN, sector coupling, energy transition

Iva Ridjan Skov is an Associate Professor in Energy Planning at AAU. Her research is focused on electrofuel (P2X) pathways for liquid and gaseous fuels for 100% renewable systems, energy system analysis of these pathways from a technical and socio-economic as well as policy perspectives.

Fast forward for power-to-x in Denmark: the role of advocacy coalitions in shaping policy

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Decarbonisation of the energy system is the prime focus of policies seeking to limit climate change. This requires not only a transition to renewable energy, i.e. integrating intermittent energy sources into the system by establishing cross-sectoral connections, it also entails finding alternatives to fossil fuels in sectors like transport. For many years, the transport sector has been the only sector with rising carbon emissions. Although electrification is deemed a viable option for decarbonising parts of the sector, it is not applicable for parts of heavy-duty, maritime or air transport. The European Commission considers hydrogen as one means for decarbonising the transport sector and achieving an economically beneficial transition, as indicated by the European Hydrogen Strategy, followed by member states issuing their hydrogen roadmaps and strategies. However, Denmark has chosen instead to pursue Power-to-X (PtX) strategy, indicating that hydrogen is not the only end-product needed for the transition. Instead, hydrogen should be seen as an emission-free fuel, raw material and an energy carrier to be further processed into PtX fuels or so-called electrofuels. This is remarkable: not only is it a strong statement for one member state, but the prioritisation of PtX was also swiftly adopted. It appears there is widespread agreement as to the necessity of developing PtX fuels for meeting political targets. Furthermore, methanol, ammonia and e-jet fuels are generally considered the desired end fuels. This paper investigates the roles actors and coalitions have in shaping the Danish PtX strategy, constituting PtX as a needed part of the future energy system. The paper is based on an analysis of future energy scenarios, strategies, roadmaps and suggested policy changes proposed by various advocacy coalitions in the PtX field.

Keywords: power-to-x, PtX, electrofuel, advocacy coalitions, policy

Marie-Alix Dupré la Tour was born in Paris, France in 1995 and graduated from Mines ParisTech in 2018. She started her PhD with RTE (French TSO) and CIRED (International Research Center on Environment and Development) in November 2019. She aims to simulate the energy system in Europe in 2050.

Aggregation of heat networks for their integration in European scale sector-coupling studies

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Efforts to achieve decarbonization are accelerating in Europe, particularly since the Green Deal. These efforts are characterized by a strong support to electrification and vector coupling. This would help to decarbonize all energy carriers (especially methane, hydrogen, heat) and improve their operation (particularly of the power system) through flexibility enhancements. Heat networks, in particular, can be an interesting source of flexibility for the power system. These flexibility gains will depend on the sourcing of heating networks, which is a crucial issue in energy forecasting: while some countries (such as France) tend to opt for biomass to green heating networks, others, such as Denmark, are switching to electrification.
Modelling of heating networks at the urban scale has been carried out for eight representative cases of these networks. Two cases were designed to represent current typologies, and six future typologies, to reflect the technologies and interactions between vectors that will develop (hydrogen cogeneration, long-term storage, solar thermal, geothermal, heat pumps, virtual storage in the distribution pipeline).
After validating the operation of these unitary heat networks, an aggregation work was carried out, so as to integrate these networks on a larger scale, in a European energy system model, combining the power, methane and hydrogen vectors. To reduce the complexity and therefore the computation time of the simulation, all the heat networks of a country are modelled in the

same area. To avoid the production of a local heat network to supply the demand of another, it was thus necessary to include fictitious constraints of availability and operation.
The large-scale impact of the development of heating networks has been studied. The production mix of district heating networks has a significant effect on the power system. This phenomenon was studied for different district heating generation portfolios, electrified (heat pump generation) or biomass-fuelled (via cogeneration in particular).

Keywords: Vector coupling, flexibility, energy carriers, power system, decarbonization, district heating

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Øyvind Vessia is Head of Energy Economics at Ørsted and is responsible for regulatory affairs in the continental European Markets. He focuses on developing the agenda and strategy for regulatory efforts in EU countries. Øyvind Vessia joined Ørsted in February 2016, first as Head of European Affairs.

Unlocking grid savings through PtX when integrating offshore wind energy

Øyvind Vessia, Ørsted

Øyvind Vessia (presenter)

Offshore wind energy will play a crucial part in reaching Europe's net-zero targets. Collectively, Europe has an offshore wind energy target of at least 100 GW offshore wind installed by 2030, and studies point to 450 GW of offshore wind being needed by 2050 for Europe to become climate neutral. The Esbjerg declaration points to 150 GW in DK, DE, NL and BE. Massive grid infrastructure investments will be needed to integrate such large volumes of variable offshore wind production.

In part, a solution to this challenge lies in the intelligent interplay between large-scale offshore wind and PtX production. By deploying assets with a flexible consumption pattern such as electrolysis and integrating these with offshore wind farms, the required grid build-out can be dramatically reduced. By placing PtX assets at an energy island or at the connection point in the onshore grid, they can peak shave the generation allowing for a more stable flow of electricity into the grid and a reduced need for grid access.

At Ørsted, we consider the grid costs of integrating offshore wind energy as a useful parameter for developers to compete in public tenders on radially connected offshore wind farms in order to unlock a smarter and more cost-efficient green transition. As for hybrids – such as the Danish Energy Islands – smart integration of large amounts of wind power requires closer dialogue and cooperation between the TSO owning and dimensioning the interconnectors and PtX developers on the location for PtX factories and the terms under which PtX can operate at such locations. This dialogue will be essential to reach the full potential for saving transmission grid investments. Asides from contributing to a cost-efficient integration of offshore wind, this approach will further help kick off the PtX industry by securing the PtX facility access to green electrons.

In this presentation Øyvind Vessia will elaborate on the potential for saving grid build-out when taking PtX into consideration in planning grid connection of offshore wind energy.

Keywords: Transmission, Grid, PtX, Hydrogen, flexible consumption, green electrons, offshore wind, grid integration, grid savings, buffer, infeed zone, market dialogue, green transition

He completed his master's degree in electrical engineering at University of Applied Sciences Munich. Since 2018, he has been working in science at the independent research institute FfE. He focuses on studies regarding load change due to integration of new consumers into distribution grids.

Assessment of Resulting Loads and Constraints Applying Clustering Approaches for Determination of Representative Distribution Grids

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At the distribution grid level, the German power grid at the low-voltage level has a length of over 1,000,000 km. Compared to the medium-voltage level (approx. 500,000 km) and the high-voltage level (approx. 100,000 km), the low-voltage grid accounts for the largest share. With the increasing addition of distributed generation units in the lower grid levels as well as the expected integration of a large number of charging stations for electric vehicles in the private and commercial sector, these low-voltage level distribution grids are confronted with previously untypical load situations.

In order to address these emerging scenarios and to initiate possible expansion measures or to install intelligent operating equipment, comprehensive simulations of the developing scenarios are reasonable. Particularly the low-voltage grids differ considerably in terms of their topology as well as the consumption patterns of the connected loads. In order to make universally valid conclusions, a considerable number of grids must therefore be simulated, which is associated with a high computational effort and thus also a time-consuming process. This problem raises the question of how many grids of a certain stock need to be simulated in order to achieve a valid representation about the resulting grid load. An evaluation of cluster processes following different criteria aims to address this issue. The objective is the selection of the least possible amount of representatives with the least possible deviation regarding grid load.

Based on a database of 1,206 grid topologies and their associated grid load conditions, which was determined simulatively as part of the "Bidirectional charging management" project, various cluster criteria are experimented with in order to identify the best possible representatives. Various cluster categories are identified, defined, tested and evaluated in the process. These include self-defined categories as well as categories from the literature that classify parameters such as grid characteristics, load, and utilization in various combinations.

After identifying the representatives by applying the cluster algorithms, their representativeness is evaluated.

Keywords: Energy System Analysis, Future Grid Load, Distribution Grid Case Study, Representativeness in Distribution Grids, Cluster Algorithms, Electrification in Distribution Grids

From 2007 to 2020 he was head of the department and the competece center district heating of the energy agency in Baden-Württemberg. In the beginning of 2018 he launched togehter with the Danish partners the German-Danish dialogue district heating. Since 09/2020 he works as freelance collaborator.

Estimating the trench length and linear heat density for municipal heat planning – a comparison of different methods

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As part of strategic heat planning, settlement areas are divided into zones for district heating grids and decentralized heat supply. Therefore, it is important to have a tool calculating trench lengths and linear heat densities with reasonable effort.
The parameter of effective width has been introduced by Persson/Werner in 2010. The effective width w is defined as ground area divided by the trench length within the ground area (w = AG/lT). It can be estimated empirically from existing district heating grids. The HOTMAPS-Toolbox implemented a suitable calculation method for heat distribution costs based on effective width. This concept is further developed in the ongoing sEEnergies project.
Within the scope of the ANSWER-Kommunal project two novel approaches have been developed. One uses official geodata, to calculate the route of the distribution pipes in a semi-automatic manner. Therefore, distribution pipes are generated along the street network and from there on within the shortest distance to heated buildings using GIS.
Comparing the generated trench length for 17 municipalities against the effective width, the total amount is about 20% longer than with the HM-Toolbox-results and about 30-40% shorter than with the sEEnergies approach. Thus, the heat distribution costs are underestimated or overestimated in the same range.
Further, the generated grid has been used to assess the usability of machine learning to predict trench lengths within 100x100 m grids. Using the official cadastral building footprints 24 attributes are calculated that describe their distribution within each respective cell and their neighboring cells. For prediction Random Forest is used, where 50% of grid cells are used, with the known trench lengths from the first approach as input training data, and the other 50% to evaluate the applicability of the method. First results show a high R^2 value of 0.64.
The application of the proposed GIS and machine learning approaches are possible alternatives to effective width as both approaches lead to more accurate results. The benefit of the latter

approach is, that it can easily be implemented to calculate an approximation of trench lengths on a large scale without much data input and thus providing an ideal basis for heat planners.

Keywords: strategic heat planning, zoning, trench length, linear heat density, heat distribution costs, effective width and plot ratio, GIS-application, machine learning

He leads in the development of TNO's portfolio for smart and future-proof heat networks, the main goal of which is to help developers of heat networks with better design and control of heating and cooling grids, making these more affordable, sustainable and flexible

WarmingUP Design Toolkit for Future-proof Heat Networks

Martijn Clarijs, TNO, the Netherlands

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In the Dutch innovation program WarmingUP (https://www.warmingup.info/), 50+ partners from the value chain of collective heating systems are working together on various innovations related to topics ranging from sustainable sources such as geothermal and aquathermal heat, heat storage, heat grids and societal acceptance. Under the topic of system integration, 10+ partners have developed a beta version Design Toolkit (https://www.youtube.com/watch?v=xrPCmpUxEAI). It contains state-of-the-art models, solvers and optimizers that, in conjunction with GIS-based data layers, support the development of thermal networks in the planning and conceptual design phase. The Toolkit allows scenario comparison and optimization of all elements of the heat network from multiple heat sources to consumers on daily, seasonal and annual timeframe, quantifying the impact of design choices on system-wide KPIs, such as CAPEX, OPEX, CO2 emissions and flexibility-related KPIs of the network. The beta version will become available in spring 2022 as (1) a free of cost version, via a downloadable instance running on a local machine and (2) in autumn 2022 as a SAAS version, running in the cloud, under a service contract. Different developing partners will present on the why, how and what of the Toolkit and its value for the community of planners, designer, engineers and users of heat networks.

Keywords: WarmingUP, heat networks, planning, design, control, holistic, transition scenarios, public-private, dynamic calculations, optimization,

WARMINGUP | DESIGN TOOLKIT

https://www.youtube.com/watch?v=xrPCmpUxEAI

Mostafa is a researcher associate and PhD candidate at the Energy Economics Group in TU Wien. He holds a master's degree in Power Systems Engineering from TU Munich. He significantly contributes to energy system modelling, notably in the context of H&C potential analysis and system/grid planning.

Overview of district heating potentials in EU-27 countries under evolving DH market shares and ambitious heat demand reduction scenario

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The objective of this paper is to provide an updated assessment of the DH potentials across EU countries considering future development of both heat demand and DH connection rate.
In this paper, we take an overview of current heat demand and DH connection rates in EU Member States as a starting point. Based on a scenario for decarbonizing heating system, the annual changes of the heat demand as well as DH connection rates till 2050 is modeled. In this procedure, the most recent studies for the calculation of effective width and linear heat densities were used. Accordingly, economic DH areas and DH potentials in each member state is obtained.
The results show a mixed picture of DH expansion in different member states. For example, for maintaining share supplied by DH from the total heat demand, it is necessary to expand and increase the existing DH girds, often due to the decreasing heat demand. While average DH grid costs in most of the Member States ranges between 23 to 30 EUR/MWh, there are a few countries like Estonia that demonstrate lower grid costs due to high connection rates and high heat densities in DH areas. In contrast, in countries with low starting connection rate like Netherlands the overall grid cost leads to prices above 30 EUR/MWh. The study shows that in EU-27 countries, more than 40% of the heat demand is in regions with high potentials for implementing DH. Furthermore, around 70% of the heat demand in identified DH areas can be covered by DH.

Keywords: district heating, potential, evolving heat demand, evolving connection rate

He has worked for over 20 years as researcher and consultant in areas related to energy performance and sustainability assessment in the construction and energy sectors. He currently works with energy system models and GIS building stock models, supporting city energy planning.

City zoning for heating and cooling : Methodology for prioritization of solutions at building or district scale

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While some cities already have district-based heating or even cooling networks, the majority still rely on individual solutions and with a high share of fossil fuel use.

In most of those cities, the change to the heating and cooling supply is being approached from a building or even apartment scale, and whenever solutions are cost-effective and meet local and national regulations.This leads to a scenario where various types of heating systems can coexist in multifamily buildings, and at different stages of their service life. Planning for district based efficient and renewable solutions becomes then increasingly difficult.

This paper presents a methodology for pre-selecting heating and cooling solutions through a zoning process, doing a diagnosis for heating and cooling within the city, and prioritizing between the different heating solution (?)

A first step of the methodology is to developing a GIS city building stock energy model,, based on generally open data such as the city's GIS data platform, cadastre, or the regional energy certificate database. With this information, different outputs of the model are prepared, including individual building characteristics ,heat density or heating and cooling usage. These outputs of the energy model are then evaluated in combination with urban planning and resource availability layers.
Following a classification of each heating and cooling strategy for the different layers, a weighted overlay analysis allows a georeferenced representation of the viability of different heating and cooling solutions. An example analysis is presented for the city of Bilbao, Spain.

Results of the analysis provide insights on which are the best solutions that can be applied to decarbonize the different districts within the city, and support energy planning policies and strategies.

Keywords: Heating and cooling maps, decarbonisation, positive energy districts, GIS , building stock,district energy

Chilean citizen, Civil Engineer and Master's Degree in Mechanical Engineering from the Universidad de Santiago de Chile.
Since July 2015 he has been working in the area of solar heat for industrial processes & district heating in the solar energy centre of Fraunhofer Chile Research.

Determination of the technical-economic potential for the development of district heating projects in each commune of Chile

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In Chile, the composition of fine particulate matter (PM2.5) emissions to the environment is strongly influenced by residential wood combustion, with a percentage of participation of more than 80% of the emissions of this type of pollutant. This fact has caused that from the capital of the country to the south (the coldest part of the country) more than 85% of the MP2.5 monitoring stations show records that exceed the limit value of the current regulations in force. In terms of health, MP2.5 pollution caused approximately 3500 deaths in 2017, with a cumulative social cost of approximately US$2500 million.
Fraunhofer Chile is promoting the use of district heat as one of the alternatives to replace the current use of firewood in the center-south of the country. This option is consistent with the country's decarbonization pathway, which in turn would allow avoiding high mortality and morbidity rates with their associated social costs.
This study shows the district heating (DH) potential in Chile, for the different regions and communes of the country, determined according to the energy density required in a locality for the technical-economic feasibility of developing a DH project.
The thermal demands for heating and domestic hot water (DHW) were quantified for six types of sectors in the country: residential, hotel, offices, public administration, health and education; through the processing of multiple databases present at the country level.
The analysis shows a high potential in the country's capital, with the maximum demand and density of thermal energy. And in general, sectors with technical-economic feasibility can be found in more than 40% of the 344 municipalities that make up the country.
The results show the methodology used to calculate the thermal demands, and the results are presented in the format of heat maps at the country level, showing both the total energy demand and the demand per unit area.
As a complementary work we expect to weight the results obtained with a high spatial resolution with real data provided by the Government of Chile at a regional level. And to include at profile level the demands of some industrial sectors of the country.

Keywords: District heating Chilean potential, database processing, domestic hot water, residential heating, industrial waste heat, profile techno-economic evaluation

Prof. Dr. Bernd Möller is professor in Sustainable Energy Systems Management at Europa-Universität Flensburg, Germany. His research includes geospatial analysis in energy planning, sustainable energy access and development.

Synergies between geographically distributed energy efficiency potentials

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Energy efficiency potentials in buildings, in transport and in industry are geographically distributed. Characteristics of building stock influence end-use efficiency as well as the potential to develop district heating or heat pumps to meet the residual heat demands. Industrial processes may become more efficient, and potentially supply excess heat to district heating. Transport efficiency is subject to modal shift, the transition to electro mobility, but also the layout of urban areas. Common for all is their interlinkage in future smart energy systems, where district energy grids, charging stations and other infrastructure is critical for the integration of variable renewable energy sources. The degree to which such systems can be developed is determined by the urban tissue: the density and age of the building stock; the compactness of settlements and the resulting transport distances; and the proximity to industrial and other excess heat sources all tell which infrastructural means of sectoral coupling between energy system components may be feasible. Using high-resolution representations of energy efficiency potentials in urban areas developed in the EU-sEEnergies project, an index has been calculated for about 150,000 settlements in Europe. The sEEnergies Index uses multi-criteria modelling and an analytical hierarchy process to assess logically and semi-quantitatively the local options to harvest energy efficiency potentials according to the Energy Efficiency First principle. Results show that a majority of the urban population in the EU27 and the UK lives in areas where energy efficiency potentials are highly synergetic, allowing for cross-sectoral options for smart energy systems. Further, many locations primarily in rural Europe are challenged by low and declining densities, and the lack of close proximity and increasing distances. Consequently, and in the light of the sustainable development goal number 7, which is about access to modern, reliable, and affordable energy, the concept of smart energy systems needs to be extended to rural and socio-economically challenged areas of Europe.

Keywords: Energy efficiency, sEEnergies, GIS, energy planning

Somadutta Sahoo is a Ph.D. student currently working with regionalized energy system modeling, analysis, and planning at the University of Groningen in the Netherlands. He has a master's in Sustainable Energy Systems at the Chalmers University of Technology, Gothenburg, Sweden.

Detailed energy system modeling of a district heating network on a provincial level – a study of Groningen Province in the northern Netherlands

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Densely populated countries, such as the Netherlands, have high heat demand densities in population centers or cities. In these cities, a district heating (DH) network is economically feasible as the literature suggests. National statistics show that cities in Groningen Province located in the northern Netherlands currently have negligible contributions (<0.5%) from a DH network to the built environment. Integrated energy system models do not adequately incorporate DH network characteristics, such as network lengths, losses, piping diameters, and costs. Models detailing a DH network are mostly available on a city level without establishing the possibilities of interconnections to other cities as an electricity network would do. In addition, these models lack interaction with other sectors and energy carriers within an integrated system. In this paper, we model a DH network on a provincial level, Groningen Province, within the context of a national integrated energy system model, OPERA. Modeling involves interaction with geographic information system tooling. Spatially explicit heat sources such as geothermal and industrial waste heat (IWH) future energy potentials were made a part of the DH network structure. Relevant population centers were identified and interconnections were made between these centers, geothermal doublets, and IWH sources. A variety of technology options was added for supplying additional heat to a city and planning was done to establish their suitable locations. Preliminary modeling results show a significant increase in contribution from the DH network compared to individual heat sources in almost every city analyzed. DH penetrations were much higher compared to the current levels and compact cities with high demand densities have higher penetration compared to less dense widespread cities. This outcome signifies the impact of a detailed analysis of a low-temperature heat network on a regional level. The result also shows the effect of incorporating spatially dependent heat sources on the overall network characteristics and costs. Finally, this regionalized modeling

framework can serve as a useful decision-making tool for heating systems and network-related choices in regional policymaking.

Keywords: heat demand density, population centers, district heating, spatially explicit, geothermal, industrial waste heat, regionalized modeling framework, and regional policymaking

Vita Brakovska has an extensive experience in the field of technological innovations and public acceptance as she chairs the non-profit organisation „Knowledge and Innovation Society". Her experience in the field provides solid ground for the combination of energy research and social sciences.

Gamification in System Dynamic Modelling Simulation Tools Used to Support Transition Towards a Carbon-Neutral Energy Communities

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To accelerate the Energy Transition there is an urge for innovations. However, often state-of–art scientific-technological solutions and policy initiatives are stuck in decision-making chains and conservative behavioral pattern. Using the conventional educational tools the diffusion of innovation in society is inert and jeopardizes the climate goals.
Novel approach offering new perspective on the knowledge dissemination, social learning and engagement is a gamification (serious games) in simulation models and tools. This novel approach was used to develop single-player game. The focus of the game is the energy communities, since it is recognized by EU as a powerful instrument in fighting climate change.
Experimental game was developed as a system dynamic (SD) simulation tool and used purposefully to combine actors and experimental systems to test hypotheses, and to learn about subjects' mental models on decision-making tasks. ~100 players were introduced to hypothetical situation when government demands neighborhoods to become carbon neutral within certain time frame and players have to decide on measures from the list of proposed energy efficiency and renewable energy solutions based on his/her preferences. Given that the collective success of a carbon neutral urban energy community is driven by heterogeneous consumer motivations, social interactions, and individual adoption decisions over time, SD is useful in predicting consumer adoption of energy efficiency and RES options for different design parameter values. It allows to examine socio-technical system performance over time, wherein system behavior is subject to complex and dynamic individual human behaviors and social interactions.

Simulation learning tools with gaming elements allow understanding the complexity of the given system and evaluate the impact of each element and thus might initiate the behavioral changes at individual level. On the other hand the “black box” of the game provides analysist with useful information on the decision making drivers for each player and are summarized in paper. Based on the results effective policies and business models can be designed that are and useful for decision makers and policy makers, when laying the ground for radical technological changes.

Keywords: energy community, energy transit, energy simulation tools, single-player game, behavioral change

Richard Büchele is researcher at the Energieinstitut Vorarlberg and holds a PhD in electrical and power engineering with focus on energy economics and energy supply from TU Wien. His work focuses on integrated strategic heating and cooling planning and analysis on different regional levels.

Economic and ecological feasibility of district heating in a deeply renovated housing estate

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Overview and research question:
In the presented project the energetically-economically optimized refurbishment of two sample buildings of different ages/types located in the housing estate "Südtirolersiedlung Bludenz" are analysed, and the economic and ecological feasibility of a district heating system against individual heating systems is checked. The building types of the housing estate of 397 residential units built in 1943-62 are small/medium-sized multi-family houses representative of large parts of the stock in non-metropolitan Austria, energetically almost in their original condition and heated exclusively by individual stoves (gas, wood, oil). Since the housing estate is rented at low rents to low-income households, the equal optimization of climate protection and economic efficiency is essential in order to demonstrate solutions for the reduction of energy poverty in practice.
Method:
Two building types representative for the social housing estate are modelled in detail with the passive house planning package (PHPP) in order to calculate the current heat and energy demand. For each of the two model buildings, several thousand design variants of different energy levels and concepts are planned and tendered in modular form and the alternative of a district heating system supplying the whole housing estate will be checked for different refurbishment levels and building densities. The concepts that achieve the targeted climate target-compatible energy level at the lowest life cycle costs will be implemented. The costs and the measured energy consumption of the sample buildings will be used as a basis for the energy concept of the other buildings in the development. For the economics of a possible district heating system the remaining heat demand and density after renovation, the temperature level and the available heat sources will be crucial.
Results:
The results will show the best concepts for climate target-compatible retrofit and their indicators regarding energy demand, GHG emissions (production & operation), investment and life cycle costs, and will show if district heating is a feasible supply option within this setting.

Keywords: district heating, social housing estate, economic and ecological retrofitting

Daniel Heidenthaler is a research assistant at the Salzburg University of Applied Sciences in Austria and currently writing his PhD. His research focuses on the field of Smart Buildings and Smart Buildings in Smart Cities. One emphasis is on energy flexibility through thermal mass of buildings.

Automated urban building energy modelling approach for predicting heat load profiles of districts

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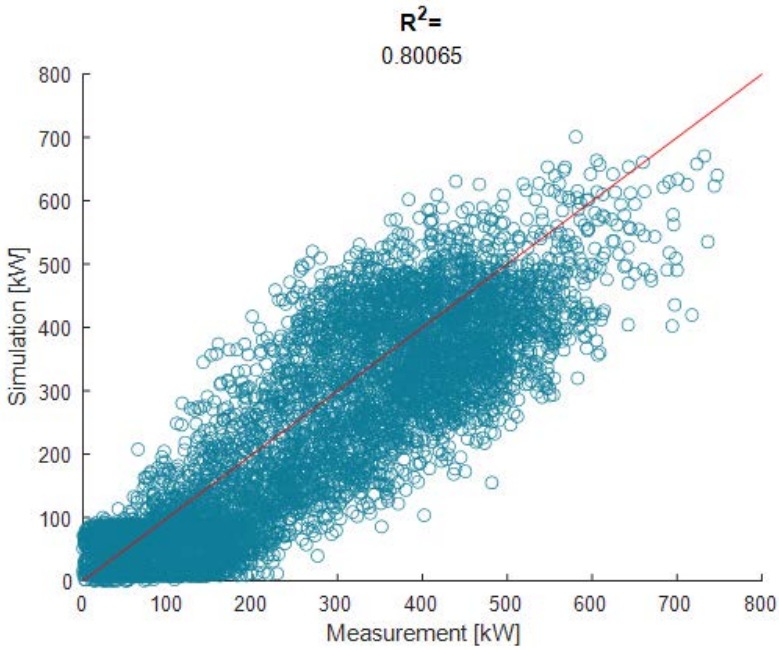
Building energy simulation (BES) plays a significant role in assessing the energy efficiency of buildings. Recently, methods for simulating and optimising energy consumption not only at building scale, but also at district scale increase more and more in importance. Nevertheless, so-called urban building energy modelling (UBEM) approaches are currently challenging due to the complexity of the energy system, required resources, available information, time as well as effort to achieve accurate results. This study provides a bottom up fully automated UBEM approach aiming at providing energy data for heating and domestic hot water on building level for whole districts in the residential sector. On the basis of energy performance certificate (EPC) data as well as airborne laser data for geometrical information and literature for detailed constructions and materials, the building stock is classified on the basis of two main criteria. First, the building stock is divided in 9 building age classes. Second, the buildings were divided into two groups regarding the thermal quality: the existing building stock and refurbished buildings. Furthermore, extended models regarding different heat emission systems as well as the existence of a buffer tank were created. The simulation models in IDA ICE are created and analysed in a fully automated procedure using MATLAB and then validated against district heating measurements of a node in the federal state of Salzburg (see Figure 1). The statistical measure R-squared is used to evaluate the models. Overall, an R-squared value of 0.80 can be reached, based on solely knowing as much as an estimation of the build-ing age class, thermal quality, type of building (single or multifamily building), heat emission system, the existence of a buffer tank and the conditioned area of the building. A close look at the simulated and measured hourly load profile indicates, that the highest differences result from summer, where only domestic hot water is used, transition period, as well as daily fluctuations. This method thus allows the estimation of an hourly heat load profile based on little information for whole districts, with emphasis on the heating period. Further improvements of the simulation models based on these observations are planned.

Keywords: urban energy modelling, building energy simulation, archetypes, energy performance certificate, heat load profile, district heating, workflow automation



Igor Krupenski is the head of heating and cooling engineering company and lecturer 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.

Converting the heating system of the historic center of Tallinn (Old Town) to a district heating system

Igor Krupenski, HeatConsult; Anna Volkova, Tallinn University of Technology

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The transition to district heating in cities has been extensively researched and is the subject of numerous studies. In the European Union (EU), buildings account for about 40% of total energy demand. At the same time, historic buildings consume 24-35% of energy in Europe. The specific thermal energy consumption in these buildings can be 8-10 times higher than in modern buildings with low energy consumption.

Current study is focused on analysis of heat supply of historical centre of Old Tallinn transition to district heating. The purpose of the study is to demonstrate the transition of a UNESCO-protected historic district to a district heating system using the city of Tallinn as an example, as well as to identify the challenges that this transition presents.

All historical properties are required to maintain the authenticity and aesthetic integrity of the property. It is important to use new technical solutions that boost energy efficiency and reduce environmental effects while keeping the object's historical significance throughout reconstruction. For the analysis, three historic centre heating system scenarios will be used:

- Scenario A. Current situation.
- Scenario B. Conversion of gas-heated buildings with central heating to district heating.
- Scenario C. Conversion of all buildings, including those with electric heating, to district heating.

All scenarios will be compared according to three indicators: Primary energy; CO2 emissions; Consumer-facing heating costs.

Keywords: District heating development , historical towns , primary energy , CO2 emissions , district heating pricing

Ari Laitala M.Sc. (Tech.) works as a project manager in Sykli Environmental School of Finland and leads research related projects in the field of real estate, energy efficiency and carbon neutrality.

Calculating existing buildings carbon footprint based on open data – role of the energy

Ari Laitala, Sykli, Taru Uotila, Sykli, Tapio Pelto, Sykli

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What are cities made of? One could say that of buildings. What is the carbon neutral cities made of then? One could say that about carbon neutral buildings. Probably so, but unfortunately, we have only very few of them. And it is difficult to get them more at a fast pace. Building stock renews somewhat slowly, typically only 2-3 per cents a year. And more, producing carbon neutral buildings is still difficult and expensive. Hereby, there is a reason to put attention to the existing building stock.

Real estate (building) is a node of numerous activities. These activities must be taken account to get a holistic view of the building related carbon footprint. Especially in the commercial buildings there is a somewhat large set of activities which are needed to keep things running. Most essentials are the real estate maintenance, waste management, smaller renovations, cleaning services, security services, lobby services, maybe workplace catering. Then there is a bunch of administrative services like property management and accounting. Some of these activities are needed in the residential and public sector buildings as well.

It is not often clear which part of these activities belong to the actual building footprint. And further, how the calculation procedure should be carried out, where to find necessary data and values for emission factors. What is the satisfactory level of details to take account and accuracy in the calculations? Is there a practical way to do all this? And, maybe the most important questions of all, do we have a factual reason to care about the carbon footprint of the buildings. To whom it could be relevant information and is there a financial motivation and business-related incentives for this activity.

In this presentation, a relatively simple calculation example is presented. Instead of organisation and building specific measured data, it is shown what kind of open data can be utilised, especially in the Helsinki area, where Helsinki Energy and Climate Atlas provides part of the data needed. The given example also suggests a robust calculation procedure based on the Greenhouse Gas Protocol (GHG). Finally, the presentation discusses about the above-mentioned questions and offers opening answers.

Keywords: carbon footprint, energy, existing buildings, fossil fuels, 3D city model, open data, Greenhouse Gas Protocol

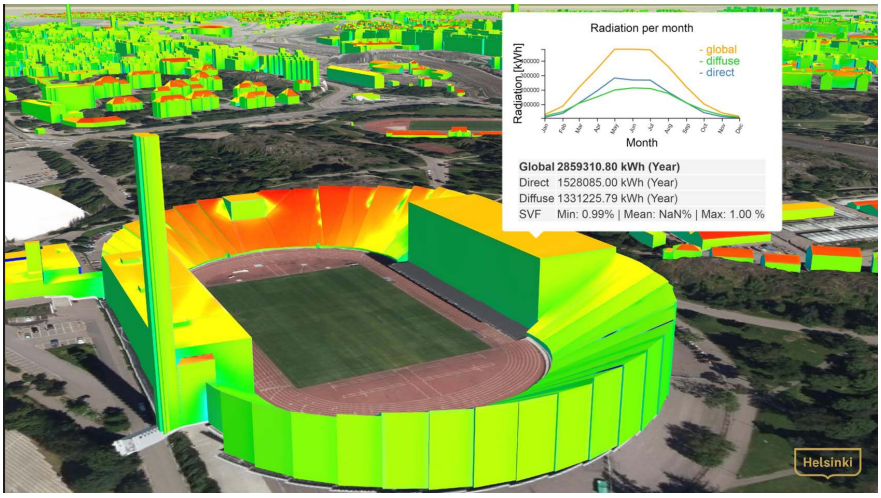

Figure: Digital 3D city model, Helsinki Energy and Climate Atlas, offers large set of sustainability related data

Poul Thøis Madsen is an ecoomist and associate professor and PhD at Aalborg Univesity working together within the SEP-group: sustainable energy planning. His area of research is mainly the macroeconomic aspect of the transition towards a fully decarbonized society.

The Consequences for Employment of investing in a Smart Energy System in the EU

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It has been debated for long how to calculate the net employment impact of going green (also called decarbonization). Most of the previous studies have been country studies or disaggregated studies. Some of the more recent studies are studies of EU or Europe. This paper review studies, published after year 2000, of the employment impact of transforming EU or Europe into a renewable energy system rather than focusing on the employment effect of specific technologies such as wind turbines. The studies try to measure the impact on employment of either renewable energy policy, the production of renewable energy or the consumption thereof. And some of the studies are historical while others are predictive. The concept of employment is demonstrated to be ambiguous: are we concerned with direct, indirect, gross, or net, and do we include induced effects as well? Some of the studies also include learning effects. All concepts are presented and discussed at some length because it is so important what we talk about and attempt to measure. In the next two sections of the paper the methods applied to unravel the employment impact estimated in the studies are briefly surveyed and compared and so is the different sources providing the data. Finally, the general results concerning the net impact on employment are surveyed, discussed, and attempted synthesized. In the conclusion it is discussed where to go from here. Is there a future for employment studies of EU as a whole? If so, do we need to develop the conceptualization and methods somewhat? And do we have the data needed to make adequate future studies?

Keywords: Employment impact, renewable energy, smart energy systems

Graeme is Professor of Heating and Cooling at London South Bank University. Starting with J&E Hall in 1983, Graeme's research has been focussed on developing sustainable heating and cooling solutions.

The generation gap! Are we using the correct terminologies in the sector?

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The term 'generation' is generally used when one technology supersedes previous versions, for instance 5G is the 5th generation mobile network. It is a new global wireless standard after 1G, 2G, 3G, and 4G networks. The same terminology has been used to describe the evolution of heat networks. Heat networks have been developed over many years and have evolved from first generation high temperature networks to those that operate at ambient temperature often classified as 5G. The term G implies that the latter technology has superseded the previous one, which was true up to when 3G heat networks superseded 2G. However, we have since had 4th and 5th generation and whilst these systems can be beneficial over previous generations, 3rd and 4th generations still have their place in decarbonizing heat. The term 'generation' could therefore be misleading in this context and this paper explores other options for terminology for referencing these technologies. The authors of this abstract are proposing to discuss this issue with the audience of the upcoming CIBSE Technical Symposium in the UK as well as with a wider European audience through the forum of the Smart Energy Systems International Conference. It is evident, that currently there are mixed views within the district energy community about the terminologies currently being used in the sector. This opinion paper aims to highlight this issue and initiate a discussion, with a view to moving closer towards a consensus.

Keywords: District energy, generations, terminology

Yannis works focus on the optimal sizing for the retrofit of District Heating Network in order to transition to lower temperatures. Previously, he worked on the optimization of the retrofit of building stocks and on decision aid methods to real estate managers.

Retrofitting second-generation district heating networks towards lower temperatures with optimal design tools

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Roland BAVIERE, Univ Grenoble Alpes, CEA, LITEN, DTCH, LSET, F-38000 Grenoble, France
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The transition of second generation district heating networks (DHN) from high operation temperature levels (>110°C) to lower values can lead to energy savings as well as constraint alleviation on pipings and substations. However, lowering temperature levels requires specific adaptations measures in the distribution system in order to guarantee demand satisfaction. Methodologies for bottleneck identification exist and can currently be applied manually.

This work focuses on the integration of a retrofitting procedure on DHNs aimed at temperature reduction using specific, adapted tools for design optimization. The approach we present can be broken down into two parts. The first one is the application of the existing methods in order to identify weaknesses in the design of the DHN preventing the retrofitting procedure. The second part, which is the core of our contribution, concerns the use of multi-objective optimization in order to propose the most efficient modifications on the DHN, which allow for successful operation. Possible design evolutions for the DHN to be proposed target central pumps, booster pumps, substation's heat exchanger sizing power and existing distribution pipes. Optimization is performed with respect to the investment cost and the operational cost. The operational cost is evaluated thanks to a non-linear and dynamical simulation of the DHN model on given scenarios, based on the DistrictLab-H software.

The novelty of our work lies in the possibility to tackle multiple types of distribution assets in order to reach an overall optimal configuration. The multi-objective optimization proposes then a set of optimal designs arbitrating between different options, with a refined view on operation for those designs thanks to the refined network simulation capacity.

The developed methodology is applied and validated on the current design of a French second generation DHN (60 substations, 260 pipe elements), using actual operational data. The peak operating temperature is successfully decreased from 145°C to 100°C, and a Pareto front of optimal solutions, including recommended retrofitting modifications, is provided.

Keywords: district heating, multi-objective optimization, retrofit, simulation, temperature lowering

Dr. Runge works at CanmetEnergy in the intelligent buildings group where he focuses on the implementation of machine learning in model predictive controllers for building and districts. He graduated in 2021 from Concordia University with a doctorate in Building Engineering.

A comparison of prediction and forecasting artificial intelligence models to estimate the future energy demand in a district heating system

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Forecasting the future energy demand in buildings and districts is a vital component towards the optimization of energy use and consequently the reduction in greenhouse gas emissions. This paper explores artificial intelligence approaches applied to estimate the future heating load in a district heating system. A distinction is made within this work between a prediction and forecasting based approach; a comparison is then accomplished by applying each method with prominent Machine Learning and Deep Learning based algorithms to estimate the future heating demand over 6 hours and 24 hours ahead. This analysis used available data from a Canadian district heating system in Quebec and actual weather forecasts obtained from Canadian meteorological services. All models within this work applied a grid search in order to calibrate their respective hyperparameters. Results of this work demonstrated that the prediction-based approach (with forecasted inputs) obtained a higher accuracy than the forecasting approach, that all the machine learning models obtained good accuracy with errors not exceeding 16% CV(RMSE) and closer to 10% CV(RMSE) for the top performing models. Furthermore, the LSTM and XGBoost were consistently among the top performing algorithms and provided good performance over a variety of hyperparameters. The biggest difference between the two was the computational times, which observed that the XGBoost was significantly faster to train.

Keywords: District heating; prediction; forecasting; machine learning; deep learning; heating load

Anna Volkova is TalTech senior researcher and a head of research group ”Smart District Heating Systems and Integrated Assessment Analysis of Greenhouse Gases Emissions” in the Department of Energy Technology, developing the topic of 4th generation district heating
solutions.

Estonian Energy Roadmap to Carbon Neutrality

Anna Volkova, Tallinn University of Technology, Einari Kisel, Tallinn University of Technology, Olavi Grünvald, Finatsakadeemia OÜ, Andres Veske, Rohetiiger, Jaanus Purga, Rohetiiger

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The purpose of this study is to demonstrate the Estonian Energy Roadmap 2040 modelling process, taking into account energy consumption in line with expectations and higher standards of living. The possibility of the Estonian energy sector becoming carbon neutral by 2040 was assessed as part of this study.
The roadmap for achieving climate neutrality models three sectors: electricity, heating/cooling and transport together, with the aim of reducing overall energy consumption, as well as ensuring sustainability, security of national supply, and the implementation of balanced economic principles. Balanced economic principles, in this case, mean high resource efficiency and lower subsidies. The modelling results compare the energy demand, energy mix, and carbon emissions for these sectors in 2030 and 2040 to those in 2021. The study estimates the investment required to achieve carbon neutrality in the Estonian energy sector.
In addition to traditional economic indicators, the overall impact of activities on the environment, the preservation of the Estonian population's well-being, and economic feasibility are all considered while assessing the future economy.

Keywords: energy roadmap, energy policy, carbon neutrality, transport

He is a PhD candidate in College of Economics and Management of Nanjing University of Aeronautics and Astronautics, mainly focusing on pathways for energy transition.

Expanding district heating to southern China: Current status and future trend towards 2060

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District heating plays an important role for low-carbon transition of China's heating system, but it is not available in southern China currently. There is still a debate on whether district heating should be expanded to southern China. To addressing this issue, EnergyPLAN was adopted by this study to investigate the feasibility and environmental benefit of adding district heating into existing energy system of northern and southern China. Then the differences of results between two regions were assessed. Furthermore, the carbon neutral energy system in 2060 for each region has been established and the impacts of applying district heating were also assessed. Results showed that expanding district heating to southern China would decrease fossil fuel consumptions and emissions, but the system cost would be higher and unit heating cost was higher than that in northern China. However, the district heating strategy would be more competitive in 2060 and it would also reduce the adoption of negative emission technologies. These findings propose expanding district heating to appropriate place in southern China regardless of the higher cost in the short term, because it will be more beneficial in the process of energy transition to carbon neutrality.

Keywords: District heating, Southern China, Energy transition, Carbon neutrality, Regional heterogeneity, EnergyPLAN

Marek Brand works from 2013 as a senior application specialist in Danfoss Climate Solutions. His focus area is failure finding, optimization and performance documentation of the building installations in residential and commercial buildings, mainly supplied by district heating.

Decentralized district heating stations in newly built multi-apartment buildings - documenting the performance and low return temperature

Marek Brand, Jan Eric Thorsen and Oddgeir Gudmundsson, Danfoss A/S, Nordborg, Denmark

Marek Brand (presenter)

Newly built area of Lindehaven in Sønderborg consist from the mixture of multi-apartments buildings and single-family and row-houses in total with 142 households designed to comply to the latest energy and sustainability requirements. The space heating and domestic hot water (DHW) is supplied by heat from the local district heating (DH) company. To make the heat supply efficient as possible, the apartments are equipped with decentralized apartment stations, DH pipes are built with insulation series three instead of series two, and the network is designed whole-year-around with primary supply temperature 57°C, to be mixed in the local mixing loop. The aimed DH return temperature is 27°C. DHW is heated to 50°C in newly developed highly efficient heat exchanger while returning 15,8°C. The theoretical calculations expects 31% savings on the distribution heat loss compared to the case of traditional temperature design 70/30. Furthermore, reduced supply and return temperature should result in annual bonus of 220 DKK per household based on the recent DH motivation tariff.
Our aim is to document the heating energy performance of the area and compare it with the theoretical calculations. Furthermore, we aim to document the performance of the individual decentralized stations and therefore we have installed additional energy meters in one of the multi-apartment buildings on the building, risers and apartment level. We have performed careful commissioning of the space heating and DHW systems and connected all the added energy meters to the on-line data acquisition system. At the moment we are gathering data and we are looking forward to present our results.

Keywords: Decentralized stations, multi-apartment buildings, low return temperature, continuous performance monitoring, validation of calculated heat losses, motivation tariff

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.

Costs and potentials for heat savings in existing buildings in Europe

Marcus Hummel, e-think energy research; Reinhard Haas, TU Wien – EEG

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Mitigating CO2 emissions for space heating (SH) and hot water (HW) preparation in existing buildings is key for reaching climate protection goals. However, it is not straight forward to calculate costs and potentials for different buildings in the stock and to determine reasonable levels of heat savings.

This work presents a compilation of analyses with the well established building stock model Invert (www.invert.at) that were developed with a focus on building refurbishment. The aim is to understand potentials and related costs for heat savings in existing buildings, how these differ between different locations, and how these interrelate with costs and potentials for carbon neutral heat supply. The analyses are based on a detailed representation of the local, regional or national building stocks in the form of archetypes retrieved from statistics and/or local building databases. For each archetype refurbishment packages are derived by combining single measures like window change, surface insulation or heat recovery systems. Energy demand for SH and HW preparation before and after refurbishment is calculated via EN1379 taking into account user behaviour and rebound effects. The analyses considered in this work include calculations of technical potentials and related costs for 6 countries and three cities as well as economic potentials for all EU-27 countries and 5 cities.

The calculations show remarkable differences between countries and cities in terms of technical heat saving potentials and related costs. These result mainly from differences in the current state of the building stock in terms of u-values, the climate and the construction cost level. Obviously, buildings that still did not undergo a thermal renovation show remarkably higher cost effectiveness (i.e. lower EUR per MWh saved) of thermal renovation compared to already renovated buildings. Unfortunately, information on the renovation status at local level is usually not available and together with missing information on occupancy and user behaviour is a source of remarkable uncertainty in the calculations. The economic potentials for heat savings in existing buildings seem to lie in the range of 30 to 50% and remarkably depend on assumptions regarding availability and costs of resource potentials.

Keywords: European building stock, building refurbishment, maintenance and thermal renovation, heating system change, building stock model, Invert

Kevin Naik is a PhD researcher, working on data-driven model for optimising the district heating at Nottingham Trent University, GB. He has received MSc. in Robotics and MBA in Technology from Kings College London, GB and CEPT, India respectively.

Zero energy rating of residential homes leveraging wind and solar energy.

Kevin Naik, Anton Ianakiev, Ahmad Said Galadanci, Giorgio Cucca, Shubham and Ming Sun, Nottingham Trent University

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The UK aims to be carbon neutral by 2050 – an economy with zero greenhouse emissions. To achieve that target all residential properties must be upgraded to a new energy efficient standard. Domestic space heating represents the most significant part of the 37% of UK emissions from heat. At present, gas is the dominant source of heat as it is cost optimal. The proposed project will research an opportunity to move away from fossil fuel sources by utilising a combination of photovoltaic energy source and local Vertical Axis Wind Turbines (VAWT). VAWTs are more suitable for urban environment due to their lower noise emissions, lack of dependency from wind direction, lower turbine centre of gravity, lower minimum operational wind speed and higher cut-off wind speed. The helical blades distribute loads evenly, resulting in reduced vibration and smooth and quiet operation.

A Vertical Axis Wind Turbine will be virtually introduced to 2050 Homes development, a cluster of 27 houses configured to use a micro–Low Temperature District Heating (LTDH) network. The 2050 homes is part of the REMOURBAN Smart Cities and Communities H2020 project, where deep retrofitting and integrated local energy system was introduced to existing buildings (27 terrace houses in Nottingham). This economically sustainable intervention aimed to utilize the energy generated on site and achieved 78% offset to the energy consumed before the retrofitting. The integrated energy/heating system comprises a photovoltaic (PV) plant, ground sourced heat pumps (GSHP), a thermal energy storage (TES) and an electric energy storage (EES), this is a centralized, scalable energy system. The heating in the apartments is supplied by a micro energy grid operating at low temperature and the overall performance is excellent, but not zero energy class.

This paper investigates the possibility to move 2050 Homes scheme into zero energy level by using Quite Revolution QR6 helical blade VAWT. Using wind speed and QR6 power curve the potential energy generated by QR6 turbine was added into 2050 Homes energy mix in the model created in Energy Plus - Dymola dual simulation environment. The preliminary results show that two QR6 VAWT can bring the 27 terrace homes from the 2050 Homes scheme into zero energy class performance.

Keywords: Vertical Axis Wind Turbine, Wind speed, Numerical simulation, PV, Zero energy homes, Carbon neutral homes

The presenter is a PhD student in the Section of Automation and Control at Aalborg university. His field of work is space heating with focus on low energy houses heated by a heat pump and floor heating. The project, which he is associated to, is called Opsys 2 which is funded by EUDP.

Experimental energy flexibility study of space heating of a BR2020 one-family house with heat pump, floor heating and photovoltaics

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Since energy is not always needed when available, or vice versa, energy flexibility is a corner stone in the smart energy system. As the ratio between low and high availability periods increases, the need for flexibility on consumption follows. Therefore, a space heating experiment has been conducted on a real occupied low-energy one-family house aiming at revealing its capacity for space heating flexibility. The house is heated by an air-to-water heat pump (HP) in combination with floor heating (FH) and equipped with photovoltaics (PV) on the roof.

The idea behind the experiment is to investigate whether the main heat load can be delivered in short intensive bursts rather than moderate rates without violating the indoor comfort. Such flexibility allows for taking advantage of favorable situations caused by energy prices and weather. Further motivation is to challenge common convention that turning on FH during hours with high irradiation from the sun is a bad idea considering comfort. Last, the experiment is an example of how it is possible to orchestra available energy assets to lower costs.

To carry out the experiment, the heating system has been retrofitted to enable manipulation of the FH circuits and heat production from the HP. During the experiment, these capabilities are used to deliver the heat in two main bulks, first at night when the price of electricity was low then during mid-day, using available PV electricity. The results revealed a high potential for flexibility in the sense that comfort was only shortly challenged after the mid-day heating burst, despite intense sun irradiation from a low hanging sun. The bursting approach meant that periods with expensive electricity were avoided.

As an extent to the experiment, this work presents several identified practical challenges, which need to be overcome for this method to be feasible. First, the efficiency of the heat pump drops as load increases, meaning that efficiency needs to be understood. Second, it is necessary to control both HP and FH to carry out the operation. Third, flexibility is only interesting if prices

and weather is highly volatile. Last the work presents and discuss price and weather conditions which can be exploited.

Keywords: Space heating, flexibility, low-energy building, BR2020, heat pump, floor heating, photovoltaic, air-2-water, high-efficiency building.

Dr.sc.ing. Ruta Vanaga is an expert with extensive experience in building energy efficiency, especially low energy buildings. She has obtained master's degree in architecture and Phd in environmental sciences with thesis on bio-inspired climate adaptive building shell.

On-site Testing of Dynamic Facade System with the Solar Energy Storage

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EU has set a very ambitious climate neutrality goal to be reached by 2050. Decarbonization of the building stock is being called for in the EU directives and initiatives. For this to happen, besides traditional energy efficiency measures – insulating building envelopes, reduction of ventilation heat losses, improving the thermal performance of materials and systems, etc. – innovative solutions for building thermal envelopes could contribute to the common goal. One of the perspective directions is active/adaptive building envelopes, that take an active part in building energy balance. A building envelope here serves as the energy converter from the outside to the inside.

The proposed adaptive solar façade system with the energy storage described in the paper is developed at Riga Technical University. It consists of three main parts:

1) energy storage unit – phase change material (paraffin),
2) energy transfer unit – Fresnel lens for faster heat transfer combined with geometrically optimized insulation layer filled with aerogel, and
3) a dynamic outer layer that adapts to the changes in solar radiation level available on-site – flaps covered with reflective material open when solar radiation exceeds defined value and close when solar radiation level is lower.

Tests on the solar façade module are carried out under real outdoor climate conditions in the test cell that is built based on PASLINK test cell principles. The tested façade system is built in the outer shell of the test booth. Previously tested in the laboratory now solar façade system is up-scaled to the full size for testing in real climatic loads. To evaluate the performance of the proposed façade system comparative study is facilitated. Two outdoor testing booths are built. The performance of the proposed dynamic solar façade module with energy storage is compared to the performance of the traditional component of the building thermal envelope triple glazing window. The key performance indicator for this study is the energy (electricity) consumption of the heating cooling systems is defined. Each booth is equipped with the air – to – air heat pump (which works for both – heating and cooling), that ensures the set temperature 22˚C during the heating season, and 27˚C during the cooling season.

Keywords: Phase change material, energy flexibility, climate goals, adaptive building envelope, facade as energy converter, control algorithms

Antoine Fabre is a researcher from Mines Paris(CES) working in the field of district heating networks. He is currently working on an IEA project named "cost benefit study on the building secondary network for improving DH performance" led by Mines Paris in partnership with Engie and IVL.

Cost benefit analysis of retrofit actions on the building secondary hydronic systems on the district heating

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Chloé Duchayne, ENGIE, ENGIE Lab CRIGEN
Theo Nyberg, IVL, The Swedish Environment Research Institute
Kristina Lygnerud, IVL, The Swedish Environment Research Institute
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District Heating (DH) is an efficient solution to decarbonize the building heating by using renewables and industrial waste heat sources. However, one cannot increase the share of these thermal energy sources which are mostly low temperature energies without decreasing primary network return temperatures. Unfortunately, the DH networks have often been connected to buildings with their own heating distribution system which are not designed for lowering return temperatures on the primary network.

To reach the objective of lowering return temperatures on existing DH, it is necessary to improve the performance of building heating systems. This paper presents a study on the potential of retrofit actions on the secondary heating systems aiming to lower return temperatures. An assessment of the economic gains of the various retrofit actions is carried out and business models are analyzed to foster the building owners to move towards more efficient hydronic systems.

A dynamic thermal hydraulic model using Dymola/Modelica is developed including a modeling of the primary network, substations and building hydronic systems. Thirty-six hydronic secondary configurations are simulated on two different generic district heating networks for the purpose of comparing their energy impact on the DHs and their investment costs. For the economic study, the heating plant on the DH is assumed to be a combination of a gas boiler and a low temperature renewable source such as geothermal.

Several retrofit actions on the hydronic secondary systems are analyzed first in terms of the return temperatures on each substation. Temperature decreases up to 19°C have been reached. Then, the impact of lowering return temperatures on the DH is assessed in terms of operating cost reductions. Based on information on the effect of the improvement of the performance in the system, a business model is drafted that incentivizes energy performance actions.

Keywords: District heating modeling, Low return temperature, Hydronic systems, Heat tariff models

Dr. Elisa Guelpa is researcher at the Energy Department of Politecnico di Torino. Her research interests are district heating (specifically on supply temperature reduction, peak shaving, optimal management and demand response), thermal storage and modelling of large/complex energy systems.

Reducing supply temperature in existing large scale district heating

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Currently several European district heating systems are 2nd and 3rd generation, the first operating with superheated water at >100°C and pressure much higher than the environmental and the second with water at pressure close to the ambient at temperature comprises between 80-95°. As an instance, the Italian DH capacity is supplied for about 50% with 2nd generation and 50% with 3rd generation systems. To make the current DH framework suitable for future energy production, i.e. exploitation of renewable thermal energy, waste heat and heat pumps fed with renewable electricity, supply temperature should be lowered. Some preliminary analyses have shown that heating circuits supplying the building radiators can operate at T<60°C for most of the heating season. Therefore, the temperature of water supplied to the thermal substations can be much lower than those currently adopted (80-120 °C). In this context, the work aims at investigating the realistic potential of DH temperature reduction in existing DH. The investigation is done on a real case study, such that results can be considered realistic and potentially applicable to similar networks. Specifically, a 2nd generation network, currently fed at 120°C, is analysed. The limitations on the reduction of supply temperature that arise in the thermal network and in the substations are considered. In particular the oversize of the system, along with additional actions that allow to exploit efficiently the existing infrastructure, are taken into account. The final aim of the analysis is to quantify a realistic supply temperature reduction that can be reached with minor modifications to the DH infrastructure. Results show that potential in terms of supply temperature reduction are not negligible, thanks to a smart exploitation of the existing infrastructure without redesign/modification that could produce unsustainable economic burdens.

Keywords: supply temperature reduction, district heating retrofit, thermal network, renewable energy and waste heat exploitation, 2nd generation DH

Nicola Di Nunzio is a research fellow at the Polytechnic of Milan, and he is focused on simplified models and district heating networks.

Reducing temperature of existing building heating systems: a simplified modeling approach

Nicola Cesare Di Nunzio, Alice Dénarié, Paola Colombo, Marcello Aprile, Mario Motta , Politecnico Milano

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The study proposed in this work is in support of the Municipality of Milan with the aim of identifying energy decarbonisation scenarios for public buildings, evaluating the possibility of lowering the utilization temperature of the existing system to connect the building to a district heating network at low temperature. Therefore, it is necessary to perform several building-plant simulations to understand the feasibility and what interventions on the building are necessary to achieve the goal. For this reason, robust and fast dynamic simulation tool are crucial for the sizing of the components of the system and for the definition of the optimal control strategy of the whole energy system.

The Energy Department of the Politecnico di Milano has developed a simulation model for the integrated evaluation of building and heating and cooling plant, with the aim of reducing the amount of input data and the geometric complexity of the building while maintaining accuracy of the results. The toolkit aims to reduce the building to a simplified Resistors-Capacitors network able to simulate the building and its heat exchanges with the external environment and among its parts.

Initially, the simplified model was used to simulate a single-family building in Milan and perform redevelopment analyses. From the simulations it has been achieved that only through a complete requalification (external insulation, windows, roofing) of the building it is possible to obtain a temperature at the room terminals of 50 °C, necessary for a connection to a low temperature district heating network.

After, the simplified model was used to simulate various types of buildings, with different geometries, number of floors, layers and located in different climatic zones. This caused adjustments to be made to the model's input to fit the results of the different test cases.

The main advantage in using a simplified model is the low computational time and the limited number of input data, which make it is suitable for early estimation of building energy needs in pre-design of new districts, test different heating and cooling systems through parametric yearly simulations, optimize control strategies (model predictive control), assess the building smartness potential (D-R, flexibility).

Keywords: District heating, Low temperature, Building, Simplified model, Retrofitting, Rc model

Since 2021, he holds a PhD in Energy and Process Engineering from MINES ParisTech (France). During his PhD thesis, he investigated the design of flexible eco-industrial parks. He is now a researcher at CEA LITEN on the field of District Heating system modeling and optimization.

Generation of simulated faulty datasets to ease Heating Network fault detection using machine learning

Thibaut Wissocq, Nicolas Lamaison and Mathieu Vallée, Univ. Grenoble Alpes, France

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District Heating Network (DHN) development is becoming a cornerstone of many European country policies for decarbonization, especially since the Green Deal. This type of system, as any technical processes, is subject to dysfunctions during their lifespan. The development of robust fault detection and diagnosis (FDD) methods is therefore a key issue to boost efficiency.
Current FDD methods can be classified in three main categories, namely quantitative model-based, qualitative model-based and process history based. While the formers rely on models (physical or logic-based), the latter use a large quantity of historical data to "learn" the behavior of the system. Due to recent improvements in machine learning algorithms together with the development of the digitalization of DHN, current research on process history type of FDD is plentiful.
The main issue with process history based methods is their inability to isolate the fault once detected. The latter is due to the absence of already identified faulty data in the database used. The approach proposed here is hybrid since it combines process history type of FDD with quantitative modeling. The fundamental principle is to constitute a database of faulty theoretical signatures using simulation models that will allow the process history based FDD to isolate the fault once detected.
Modelica-based models for simulating faults have been collected from 9 open-source libraries, analyzed and used to generate an initial database of synthetic fault profiles. We have been identifying 95 models corresponding to 7 typical subsystems (boiler, CHP, heat pump, solar thermal, storage, substations, network). After consolidating a literature review of relevant faults, we selected one preferred model for each subsystem. Some minor modifications of the model were necessary to represent some faults. Based on the selected models, we then defined relevant simulations, with suitable design of experiments covering both the occurrence of single faults and multiple faults. The execution of these simulations provides us with a database of time series for faulty and non-faulty behavior, with annotations regarding the type, severity and timing of faults. The upcoming step is then to train process history type of algorithm on this dataset.

Keywords: Decarbonization, District Heating Network, Fault detection, Fault diagnosis, Dynamic Modeling

Mrs. Lygnerud is the coordinator of ReUseHeat and has worked on low temperature heat recovery in an number of contexts. Here she has collaborated with the CELCIUS project to summarize information on metro waste heat recovery. Mrs. Lygnerud is working on business model innovation, specialized in LTDH

Metro waste heat recovery- lessons from London and Berlin

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Across EU28, 10% (1.2 EJ/yr) of the heat demand could be met by waste heat from urban sources. Out of this number 3% (0.036EJ) can be recovered from metro systems. In spite of potential, there is limited empirical information on metro waste heat recovery. It has been performed in the ventilation shaft of a station in the London "tube". It was initiated within the EU project CELCIUS (FP7) and was concluded after the project ended. In the project ReUseHeat (H2020) waste heat from the tunnel of a metro system was foreseen but failed as important stakeholders withdrew from the installation. The experiences from both projects are unique and provide important information on lessons learned for future investments in metro waste heat recovery.

In our paper, we present the three concepts and outline the potential savings of primary energy and GHG emissions. We also discuss investment payback and contractual arrangements. Important learnings are that technically, metro system heat recovery can be conducted fairly easily if they are designed for an environment inside the metro tunnel (ReUseHeat). If the design necessitates civil engineering at any large scale in densely populated areas, it is a major challenge (CELCIUS). A decisive factor for design success is the proximity between heat source and heat use. From the ReUseHeat concepts in particular, it was identified that any tunnel between heat source and use significantly erodes the business case.

As important as the technical design are stakeholder dialogues and objectives. The metro system operator is new to waste heat recovery and the threshold to ensure engagement is high. The heat recovery system installers are new to the installation and the heat customer tends to be indifferent of where its heat supply comes from. The local municipality is, as it seems, as important to metro heat recovery as the metro operator itself. It is not until there is an ambition and will to implement net zero carbon plans for urban areas that urban waste heat recovery is an evident choice. The political context must, furthermore, decide on the character of waste heat ensuring investors in urban waste heat recovery that it is equally desirable to an investment based on conventional, renewable energy.

Keywords: Metro heat recovery, Lessons Learned, London, Berlin

Sebastian Schultze is a Research Associate at Stuttgart University of Applied Sciences, a partner in the RewardHeat project.

District Energy in 2050 – Business models and sustainable finance solutions

*Kristina Lygnerud**
*Tobias Popovic**; Sebastian Schultze***

**IVL, The Swedish Environment Research Institute, Stockholm, Sweden*
***Stuttgart University of Applied Sciences, Center for Sustainable Economics and Management (CSEM), Stuttgart, Germany*

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Targeting at reducing the carbon footprint in line with the Paris Agreement District Energy (DE) business cannot be developed further by technical improvement only. Updated business models and financing schemes are needed. We present results from a project targeting to identify the conditions of the DE business in 2050. Data to understand the value DE companies can propose to customers in 2050 have been collected by means of literature review and interviews applying the design thinking method.

We identify new business conditions in 2050. We develop two alternative business models based on two alternative customer value scenarios. One is based on customers actively engaging in energy related discourse and making conscious decision related to energy. One accounts for customers less interested in being engaged, similar to current models but encompassing a higher lowest level (e.g. carbon free and efficient). It is likely that a combination of the two will apply. Differences between the business model including active customers and the current models are that the value shifts from the provision of a product to a co-creation service offer. The customer relationship is closer, resorts to digital interactive channels and built on win-win solutions. Key resources shift from central production to a number of heat sources and decentralized heat supply. Heat-pumps, storage and staff to manage the customer dialogue become increasingly important. In addition, district energy needs to be financed. Against the background of the EU Action Plan on Financing Sustainable Growth, the EU Green Deal, Next Generation EU and Fit for 55 we show that financial actors find future business models relevant and increasingly provide the funding needed.

In sum, DE companies will need to align to new circumstances where efficient and carbon free is standard. On the business model, the logic shifts to a decentralized heat supply making

distribution and storage increasingly important. The shift also encompasses a shift to co-creating solutions with customers. If the industry can successfully align to new conditions and business models it will increasingly be invested in by institutional investors.

Keywords: Future business conditions, business model, investors

Marco Cozzini, senior researcher at the Institute for Renewable Energy of EURAC Research (Bolzano, Italy), has over 10 years of experience in the field of renewable energy. He has worked in several European projects, concerning – among others – energy efficiency and district heating and cooling.

Analysis of low-temperature waste heat recovery scenarios for a case study in a conventional district heating network

Marco Cozzini, EURAC Research

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Waste heat recovery is one of the key elements at the basis of district heating sustainability. The available waste heat temperature can however strongly affect the technical implementation and the performance of the resulting system.
This contribution focuses on the recovery of low-temperature waste heat in an existing relatively high-temperature network. The considered waste heat source is modelled according to the simplified behaviour of a data centre, with rather continuous availability, but non-negligible fluctuations both in power and temperature. The analysis is applied to a case study in a subnetwork of Aalborg district heating, where loads are partially aggregated and approximated, though real pipe data are used. The amount and temperature of the recovered waste heat are parametrically varied within the constraints given by the existing pipe network, in order to understand the achievable techno-economic performance of the system. This variability can be related to the details of the actual heat recovery solution, ranging from direct heat exchange to indirect recovery through a heat pump.
The present work is part of the LIFE4HeatRecovery project, funded by the LIFE Programme of the European Union under contract number LIFE17 CCM/IT/000085.

Keywords: District heating, heat pumps, waste heat, modelling

In 2016 he started his bachelor`s degree at the University of Applied Sciences, where he specialized in the field of electrical and regenerative energy supply. In 2020 he started his master`s degree at the Technical University of Applied Sciences in Wildau in the course of automated energy systems.

Developing District-Level Energy Concepts In Aalborg (Denmark) And Wittenberge (Germany) Discussion of Heat Planning vs. District-Level Energy Concept

Felix Reinhardt, Müller und Kantor Fachingenieure für Haustechnik
Karl Sperling, Aalborg University
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The topics district-level energy concept development and municipal heat planning are currently receiving much attention in Germany and are being examined and discussed in many guidelines and projects, also at state level.
In this paper, structural differences and the associated approaches in the heat supply of the two countries Germany and Denmark are compared. The focus is particularly on the expansion of heating networks. It is discussed to what extent heating networks can play a key role in the implementation of the heat transition and what potential they have for the storage and integration of renewable energies. In order to substantiate this discussion, energy concepts are developed for two quarters (multi-family housing estate in Germany and multi-family housing estate in Denmark). The energy concepts include: renovation of the building envelope, photovoltaic systems with battery storage, power-to-heat (P2H), solar thermal energy, fourth-generation district heating with booster heat pumps. The two districts to be investigated have the same energy supply infrastructures (district heating). The challenges and opportunities of the respective infrastructure are worked out and compared with other energy supply infrastructure.
Subsequently, the extent to which the development of energy concepts at district level and the planning of municipal heating networks might create a conflict is discussed.
Finally, the approach to heat planning in Denmark and the differences compared to heat planning in Germany are discussed.

Keywords: District-Level Energy Concepts, Heat Planning, District Heating (DH), Renewable Energy

Alfred Heller has a PhD in central solar heating with pit water storage, supporting district heating systems. As Assoc. Prof. at DTU he's research was centred around Smart Cities and Innovation, leading to the HEAT 4.0 project as a PI from 2019-2022 for NIRAS consultants and DTU.

Cross System Optimisation – A HEAT 4.0 Tool

1) Alfred Heller, Technical University of Denmark and NIRAS
2) Marta Murkowska, EMD International, Denmark
3) Anders Andersen, EMD International, Denmark
4) Kyriaki Fotenaki, Enfor, Denmark
5) Torben S. Nielsen, Enfor, Denmark
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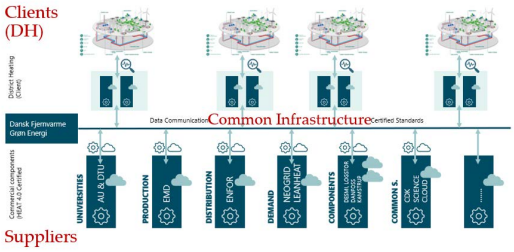
HEAT 4.0 is a cooperation between 20 actors from the Danish district heating sector, supported by the innovation Found of Denmark with approx. 5 mill. €. The project is focused on 'digitally-supported district heating' and produced a number of technical solutions to the sector. In the current work, we take a look at the innovation of a 'holistic optimization' of the district heating across components – this means across demand, distribution and production.
The project produced a number of different 'configurations' of the solution that spread from simple, not-synchronised peer-to-peer to solutions that apply common infrastructure components on top of the involved software solutions. This approach has proven to be the next generation open, digital platform for district heating that enables the operators to invest once and harvest many times, keeping the control without compromising cyber-security, privacy and operational efficiency.
Implementations will be presented in principles and value gains for the operators will be discussed on basis of qualitative methodology.
During the winter season of 2019 to 2022, data from three district heating operators in Bronderslev, Kolding and Hillerod, all Denmark, are collected to be analysed during spring and summer 2022. The results will be presented at the conference and final conclusions will be synthetised.

Keywords: digitally-supported district heating, system optimisation, system efficiency, cloud



Per Sieverts Nielsen is Senior Researcher at the Technical University of Denmark

Experiences from the Danish Innovation project – HEAT 4.0

Per Sieverts Nielsen, DTU, Xiufeng Li, DTU, Alfred Heller, NIRAS Denmark, Eva Lange Rasmussen, NIRAS, Denmark

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Industry 4.0 inspired to 'a digitally-supported District Heating (DH) innovation project, HEAT 4.0, with actors from industry, software, consulting, interest organization and universities, supported by the Innovation Fund Denmark . Niras, an technical consulting company, was leading this project with numerous parallel 'activities' that where independent but, as LEGO bricks, can be combined to new solutions – not at a micro-service level but an independent software level. In this paper we summarize the findings from the project in two groups, business relevant and scientific results. Hereby this paper is directed towards all actors in district heating. One driving idea behind the overall HEAT 4.0 platform is a 'holistic view' on the system. This work presents the scientific and commercial results of the project in a overview. Within the scientific domain, we gained additional insights into optimization of

- production component: regarding to sector coupling, waste heat integration, bidding to the electrical markets
- network: regarding temperature control with consecutive heat loss, flexibility in the net and application of heat meters for network control
- demand side: controls on various levels, from the building as a whole to individual heating and cooling components – special focus has also been on hot water consumption, flexibility on demand side, digital twin, semantic modelling of buildings for computational goals
- forecasting: local weather, demand, flexibility forecasts
- cloud system and computing: design for research, innovation and education (Science Cloud for CITIES), data management, regulatory, privacy and cyber security framework, commercialization of research infrastructure
- business modelling from a scientific point of view

, and much more.

The commercial results of the project are spreading from the HEAT 4.0 consortium that is an open framework for cooperation, a HEAT 4.0 Ready label for software and hardware that complies with (software-) technical requirements, enabling integration with other solutions in the solution portfolio, the role of an Integrator and 'common infrastructure' solutions. The scientific approaches are implemented in software solutions, communication standards and a cloud implementation of an open data platform.

Keywords: digitally-supported district heating, scientific methods, technical solutions, software

Alex A.S.A. Kalaee has a background in quantum physics with a PhD from Lund University in Sweden. He now works in R&D at Neogrid Technologies 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 operation of building heating to unlock energy efficiency

Alex Arash Sand Alsing Kalaee, Pierre JC Vogler-Finck, Anders Larsen, Per Dahlgaard Pedersen; Neogrid Technologies ApS

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The European building sector represents about 40% of the continents's energy demand (with a major share going to water and space heating). In order to achieve the green transition it is necessary to adequately activate this component of the energy system.

For over a decade, Neogrid Technologies has developed a cloud platform to support efficient and flexible operation of building HVAC systems through data-driven monitoring and optimization. This platform operates commercially on several hundreds of buildings, and supports a number of leading demonstration projects in Denmark both within the district heating and electricity sectors. Recently, features supporting operation of local aggregates of systems were added to support community-level operation.

This presentation focuses on field experience from our data-driven operation, both in terms of results achieved and challenges encountered along the way.

Keywords: energy efficiency, energy flexibility, digitalisation, control technology, building heating operation, data-driven solutions, control

Director at the Danfoss Climate Segment DBL Application Centre. This includes internal and external consultant focusing on energy systems, feasibility studies and related system and component development.

Adaptive control strategy for domestic hot water storage tank supplied by district heating

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In light of the continuous requirements for increased energy efficiency and renewable-source utilisation, the district heating supply temperature will inevitably be reduced where possible. A low district heating return temperature is necessary to realise this future trend.
An adaptive tank charging control principle was developed and tested for the domestic hot water system in three multi-apartment buildings sites. The developed control is compared to a standard reference control strategy concerning maximum capacity demand and DH return temperature.
This presentation includes the measurements of the typical daily, weekly and seasonal domestic hot water consumption and control of the storage tank, including a qualitative discussion of the measured data.
The work is carried out as part of HEAT 4.0 supported by the Innovation Fund Denmark J.nr. 8090-00064B

Keywords: control, domestic hot water, district heating return temperature

Kevin Michael Smith is an Associate Professor in the Department of Civil and Mechanical Engineering at the Technical University of Denmark. His research interests include the design and ongoing commissioning of heating and ventilation using equation-based simulation and grey-box modelling.

A novel controller using minimal district heating flows to charge domestic hot water tanks

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Abdelkarim Tahiri, Technical University of Denmark;
Jan Eric Thorsen, Danfoss DBL Application Centre;
Christian Anker Hviid, Technical University of Denmark;
Svend Svendsen, Technical University of Denmark.

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In buildings served by district heating networks, thermal storage tanks in domestic hot water systems provide a means to reduce peak demand. However, the typical charging of these tanks is suboptimal, using higher district heating flows than necessary, resulting in excessive return temperatures. This harms the network efficiency by increasing the heat losses from return pipes while decreasing the efficiencies of condensing biomass boilers, common in modern networks. The authors propose a novel control concept that optimises tank charging by effectively minimising district-heating flows while satisfying comfort and hygiene requirements. The authors first devised a control scheme using measurements from two energy meters, but one could not implement these controls broadly without significant investment. Therefore, the authors generalised the control scheme for broad application in domestic hot water tank systems, requiring only one additional temperature sensor. The control scheme used a two-stage proportional gain, realising minimal flows during off-peak periods, which maintained cold water at the tank's bottom. The authors tested and refined the two-stage control scheme in a validated Modelica model. The model mimicked an actual domestic hot water system from a multistorey residential building in Denmark, validated with real measurements. The authors implemented the two-stage control scheme in the actual building, effectively reducing the total district heating flow by 23.6% while reducing the energy-weighted district heating return temperature by 7 °C when compared to the conventional thermostatic control. These results accounted for differences in the tapped flows and temperatures of the domestic hot water and the variation in cold-water temperature and district heating supply temperatures. Additionally, the algorithm performed well when configured with different constraints on the valve settings – for each section of the two-stage

proportional gain – demonstrating robustness with minimal configuration effort, making the control scheme broadly implementable.

Keywords: control, domestic hot water, district heating return temperature, Modelica

Larissa Beierlein is a member of the Heat Transformation team at FfE. She works as an energy consultant for municipal and industrial partners.

Holistic comparison on existing guidelines for the development of heat transformation guidelines

Larissa Beierlein, FfE; Britta Kleinertz, FfE; Katharina Gruber, FfE; Yasmin Abu Trabi, FfE
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Over the past years, energy transition ambitions have switched from a sole regard of the electricity supply sector further towards industry and heat demand. Studies have shown that in the building sector climate neutral solutions exist, but due to the low transformation velocity, communal heat demand transformation could be to slowly to reach climate goals. Therefore, several guidelines to allow the development of a heat transformation strategy and associated research descriptions, based on a holistic analysis, have been published. However, these guidelines have different advantages and disadvantages as well as different targets regarding the granularity of the transformation strategy strived for (definitions for heat transformation granularity see [1]).
In this research, a general flow of heat transformation strategy guidelines was derived from a comparison of all known guidelines and according studies. Several criteria for the assessment of strategy guidelines were defined, based on a literature review on criteria for guidelines and own experiences. Furthermore, exemplary six different guidelines were assessed according to these criteria. Based on a pairwise comparison of the criteria, an overall ranking of the guidelines from the perspective of a service provider for an Integrated, viable strategy [1]. Moreover, the final result is compared to the criteria prioritization based on the discussion with ten district heating system operators.

[1] Kleinertz, Britta et al.: District heating supply transformation e strategies, measures, and status quo of network operators' transformation phase. In: Elsevier Energy Energy Volume 239, Part B, 15 January 2022,. Munich: Forschungsgesellschaft für Energiewirtschaft mbH, 2021.

Keywords: Heat transformation, district heating, energy efficiency, renewable energies

Chartered Engineer specialising in technical and economic optimisation of new and old DH. One of the authors of the CIBSE Heat Networks Code of Practice and the UK HIU Test. Exploring how PV/wind with DH improves viability. Experience in commercial ESCOs, but inspired by community / co-op ownership.

Scope for hybrid PV to improve GSHP CoPs and reduce ground loop size.

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Hybrid PV often seems to aim to deliver water at DHW temperature at which temperatures the PV module is less efficient at both electricity and heat generation. GSHP designers, in the UK at least, seem to expect good CoPs from heat pumps that only ever extract heat from vertical boreholes, where the resultant long term ground temperature is much lower than the undisturbed ground temperature. This paper explores the opportunity to use hybrid PV, nominally designed to supply heat for swimming pools i.e. up to 30°C, to directly supply heat pumps and recharge ground loops. This lowers the operating temperatures of PV, increasing their output, increases the ground temperature to improve the heat pump CoP, and reduces the required size of the ground loop reducing the capital cost. The study will combine the modelling of the ground loop in GLD (Ground Loop Design) and heat demand and heat pumps in energyPRO. The analysis will include the use of the PV generation to power the heat pump and the of shorter-term thermal storage to maximise the utilisation of the PV to lower the annual cost of heat generation. The case studied will be that of a small off gas grid village, where the area for required ground loop and PV array could be found.

Keywords: PV thermal, heat pumps, ground loops, GSHP, thermal storage

Kristian is a PhD candidate in the Renewable Energy and Energy Efficiency group at The University of Melbourne. He holds a BSc and MSc in Building and Architectural Engineering from the Polytechnic of Milan and has industry experience working on building systems, real estate and energy.

Fifth generation district heating and cooling: opportunities and implementation challenges in a mild climate

Kristian Gjoka, The University of Melbourne; Behzad Rismanchi, The University of Melbourne; Robert H. Crawford, The University of Melbourne.

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Fifth generation heating and cooling systems (5GDHC) can provide simultaneous heating and cooling, and, in principle, allow for the energy exchange between user with different needs. These key features make 5GDHC be better suited in climates with similar heating and cooling demands where these synergies can be better exploited. However, so far, every application of the technology has been in heating dominated climates with mixed results in terms of viability. In this paper we propose and model a 5GDHC in the Australian context, investigating the opportunities and implementation challenges in a milder climate with higher cooling demand. The 5GDHC performance is compared to a business-as-usual system, tailored to the selected location. The successful implementation of a 5GDHC system in Australia can create new market opportunities and can pave the way for the adoption of the technology in countries with no established history of district heating systems.

Keywords: district heating and cooling, 5GDHC, smart energy systems, heat pumps

Oddgeir holds a PhD in engineering, he has been with Danfoss for over 10 years. His focus area is the future development of the district energy sector and its role in an integrated smart energy system.

Cooling as an integrated part of 4th generation district heating

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Jan Eric Thorsen, Danfoss A/S
Marek Brand, Danfoss A/S

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As heat pumps become increasingly more common technology in the decarbonization journey the concept of comfort cooling during the warmers periods of the year is expected to arise profoundly. One can expect that once a certain cooling penetration is achieved it will set the norm for thermal supply technologies to new and existing buildings under renovation. For an infrastructure like district heating the potential future comfort cooling demand of residential buildings can become a significant challenge. This presentation investigates the possibility of addressing the residential cooling demand by a building level heat pump that utilizes the district heating system as a heat sink for the heat extracted during the space cooling operation. The solution enables 4th generation district heating systems to extend the service of heating to providing cooling to its users. At the same time the district heating system enables distributing the related heat to other heat users or means for efficient storing of it for later use.

Keywords: district heating, cooling, heat pumps

Catarina is a Senior Research Fellow at London South Bank University with 15 years' experience working on research projects in the areas of heating and cooling. She is the Project Manager for GreenSCIES a large consortium project on local smart energy networks that combine heat, power and mobility.

Driving success towards zero carbon energy targets for UK's Local Authorities

Ana Catarina Marques, London South Bank University. Helen Turnell, London South Bank University. Phil Jones, Building Low Carbon Solutions Ltd., Chris Dunham, Carbon Descent Projects Ltd., Matthew Fox, Barnsley Metropolitan Borough Council. Akos Revesz, London South Bank University. Graeme Maidment, London South Bank University.

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This paper draws on three case studies which showed encouraging economic results for meeting net zero carbon emissions targets through smart local energy systems (SLES) for the community in different geographies; London, Birmingham and Sheffield. The work explored opportunities for implementing SLES towns with a range of demands and varied local industrial heat sources. The blueprint for the GreenSCIES SLES was developed in Islington, London, and consists of a 5th generation ambient loop district heat network with electric vehicles, storage and solar PV. This network allows for heat sharing between buildings and applications for heat recovery from local sources. In Birmingham the design was aimed at improving a previously proposed conventional 3rd generation district heat network, connecting new developments and existing local authority high-rise apartments. A significantly expanded scheme reaching residential homes and non-domestic properties included waste heat from a local foundry and included solar PV and electric vehicle charging points. In Sheffield the design used low-grade waste from a local glassworks and considered old mine workings as a means of storing and recovering heat, allowing for seasonal storage of heat for resilience to the heat available from the glassworks industry. The work demonstrates the importance of collaboration between academics, LA and Industry and proves the benefits and adaptability of the original GreenSCIES concept for success in providing a pathway towards net zero carbon urban areas.

Keywords: Heat networks, industrial waste heat, smart local energy systems, renewables, electric vehicles

He is a researcher at the e-think. He holds a bachelor's degree in Applied Physics from Technical Unversity of Vienna (TUW). His research focuses mainly on energy demand modeling.

Evaluation of Gas Demand in Space Heating and Hot Water Preparation at NUTS 3 Level regarding the Dependence on Russian Natural Gas

Bernhard Mayr, e-think

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The European Union follows the objective of becoming carbon-neutral before 2050. To achieve this goal, a high share of fossil energy carriers must be replaced by renewables. Many scenarios have been developed since then, portraying a European Energy System based on renewable technologies. These scenarios envisage a gradual phase-out of the individual fossil energy sources in the order of their CO2 emission intensities from the largest to the smallest. Natural gas, which is considered one of the 'cleanest' fossil energy sources, should be the last to disappear from the primary energy mix.

However, since the Ukraine crisis, the European Union (EU) aims to drastically reduce the import of Russian natural gas for political reasons. In the short term, the regions that were previously supplied mainly with Russian natural gas will have to cover their needs from other sources. Since overland transport is based on transport via pipelines, it is obvious that these regions should be supplied from pipelines from the north, south or west. Due to the limitation of the transport capacity of the pipelines, not all regions can easily switch to this option. Especially the eastern part of Europe has a high dependence on Russia's natural gas supply.

Thus, this work aims to evaluate the gas demand in the EU at NUTS 3 level for space heating and hot water preparation. The evaluation follows a top-down approach based on the www.hotmaps-project.eu heat density map, the capacity map of ENTSOG and national data on gas demand.

All input data used in this work are publicly available. Finally, the work can provide an assessment of which European regions could potentially continue to be supplied with gas from other sources and in which regions the gas supply is potentially endangered in such an exit scenario in the future.

Keywords: Natural Gas, Demand Estimation, NUTS 3, Transport Capacities, Gas phase-out

Ali is graduated in mechanical engineering and he has obtained his PhD at UFMG/Brazil in energy area with thesis title of "Thermodynamic Modeling of a 4GDH system in Brazil". Currently, he is project leader of monitoring part of COOL DH project as a post-doc researcher at Lund University.

Xplorion: An Innovative Sustainable Building Supplied by Low and Ultra-Low Temperature District Heating System

Ali Moallemi

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Xplorion is a multi-family and passive house building in Lund, Sweden. Xplorion hosted the first group of inhabitants in November 2020. Climate-smart solutions have been used to ensure sustainable living in this new-built building. Three solutions within COOL DH project are demonstrated in Xplorion: 1) An Ultra-Low Temperature District Heating (ULTDH) demo, 2) An innovative three-pipe system, and 3) Flat stations as a new concept in Sweden.

A ULTDH demo including a hot water topping powered by local PV cells is installed to supply heat in Xplorion. The distribution temperatures can be lowered in such a demo to increase the share of Renewable Energy Sources (RES) and surplus heat. For this purpose, a heat pump can be used in the substation to increase the quality of low-grade heat. In the event of a problem, the heat pump can also be bypassed and switched to LTDH mode, ensuring that the inhabitants will not be affected.

Instead of a solution with warm water circulation that normally requires five pipes in the secondary side of the substation, an innovative three-pipe system is installed in the building to reduce energy usage even further. There is only one pipe for supply of hot water and one for return. The third pipe is for cold tap water that produces hot tap water in the flat – thereby avoiding separate hot tap water pipes and circulation pipes. The three-pipe system allows for both Domestic Hot Water (DHW) and Space Heating (SH) to be delivered with the same pipe.

Each of the fifty-four flats in Xplorion has its own flat station or district heating unit, which includes a micro heat exchanger to provide and regulate DHW and SH. The units are insulated with a removable cover, which ensures low heat losses in the system. The presented solution is used for the direct connection of the SH system with the network since the pressure of the network is not too high.

The objective of this sub-project is showing the feasibility of implementation of LTDH and ULTDH systems to provide heat in the residential buildings in an efficient and sustainable way.

Keywords: COOL DH, Flat Station, Heat Pump, Low Temperature District Heating (LTDH), Renewable Energy Sources (RES), Three-Pipe System, Ultra-Low Temperature District Heating (ULTDH), Xplorion

Ieva Pakere is author of more than 40 articles published in local and international scientific journals. Her main research areas are district heating optimisation, solar thermal and power systems, mathematical modelling, RES and energy efficiency improvement of technological processes.

Multi-source district heating system optimisation trought technical, economic and life-cycle analyses

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Implementing innovation and the sustainable development of district heating (DH) requires sound energy planning at the national and local levels.
When looking at different heat production options, following the heat source prioritisation would be necessary. The first alternative to consider is heat recovery from production plants, supermarkets, data centres and other potential waste heat sources close to the DH system. After utilising available waste heat potential, it is desirable to use solar thermal energy to cover the additional load, which can economically and without other emissions ensure thermal energy production during the summer or more extended period, using the seasonal storage system. Waste heat and the solar heat supply system can be combined with heat pumps that use solar and wind electricity when surplus renewable electricity occurs. Such a combined alternative needs to include a storage system, too, contributing to the security of the heating system. This combination of different energy sources results in polygeneration or multi-energy systems with higher efficiency and a transactive manner interacting with the power supply system.
Thus, the research analyses the potential to reach carbon neutrality of the large-scale solar DH system to make future investments in the development of the system by merging technical simulation, cost-benefit calculations, and the environmental aspects through life cycle assessment. The case study based research includes in-depth analyses of the current situation and existing operating conditions of the solar field, storage tank and additional heat sources. The future optimisation scenarios will analyse the additional thermal storage capacity, integration of heat pumps and local waste heat sources to reduce fossil fuel consumption, increase energy efficiency and optimise the heat production costs. The research identifies key criteria that allow for a comprehensive comparison of different alternatives for optimising a DH system, considering heat production, transmission, and future changes in heat load.

Keywords: multi-source district heating, solar heat, carbon-neutral energy supply, thermal storage

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Cost-effective Solar Powerplant delivering flexible electricity and district heating on demand

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The Full Spectrum Solar Energy (FSSE) project will, when introduced to the market, offer a significant part of the "missing link" in the green energy transition and offer cost-effective storage and production of electricity as well as district heating. It will contribute to the Danish as well as the international CO2 reductions by producing energy in the form
of electricity and heat from a broad spectrum of the sun's natural energy. The project combines full solar spectrum panels, large-scale heat storage at high temperatures and an Organic Rankine Cycle (ORC) appliance capable of converting the stored heat into electricity and district heating. During the FSSE project, a prototype of the system will be installed. The prototype connects directly to local distribution networks. The project partners cover the entire value chain, and the equipment developed will be tested under real conditions and for a longer period. Thanks to the ability to store energy in large quantities, the system allows a smooth production profile. FSSE also allows the storage system to be used to release energy during peak hours between 19 and 23 in the evening and 6 and 8 in the morning. The system will be able to cover the daily leveling of solar panels (PV) and help stabilize fluctuations in the energy supply from wind power caused by periods of low winds.
Project partners: ATE Energy (Development of Solar Panels and Energy Storage), Makeen Energy (Production), Sensible Energy (ORC development), DTU, SK Forsyning, Kildemosen (Production of Solar Panels).

Keywords: Full Spectrum Solar Energy, FSSE, CO2 reduction, green energy transition, energy storage, solar panels, heat storage, Organic Rankine Cycle (ORC), Conversion of heat into electricity,

Hannes Poier (MSc) is working at SOLID since 2012. Besides coordinating R&D projects he is involved in feasibility studies referred to BigSolar. Next to solar district heating his focus is on the application of absorption heat pumps in combination with solar systems.

Demonstration of large scale solar district heating integration with storages and biomass - synergies and challanges

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The demonstration of large scale solar integration in the district heating system of Mürzzuschlag, Austria aims to proof feasibility of a large solar-thermal system in combination with storage, targeting the decarbonisation of the energy supply mix and the decrease of dependence on energy imports. Next to high solar shares storages will be used for solar and biomass in parallel operation to use synergies. The first construction phase with 5,000 m² of solar area and 180 m³ of storage was implemented in 2020. A planed extension of the plant by another 2,000m² brings several challenges which have been worked on in an accompanying research project, Thermaflex (https://thermaflex.greenenergylab.at/thermaflex/?lang=en).
The producers that currently supply the grid in Mürzzuschlag are distributed over 5 locations. Solar and biomass capacities will be extended in 2022. In order to replace gas capacity, it must be ensured that this additional capacity can be distributed to other network sections at peak times. With an extended network like the one in Mürzzuschlag, this is a hydraulic challenge. The planned expansion of the storage facilities by 240m³ should be located in the network center in order to improve load balancing.
Simulations of generation schedules to ensure synergistic use of storage and to evaluate its sizing were carried out. Due to the delicate conditions of the network pressure, several variants of the generator profiles were subsequently evaluated in a separate hydraulic network simulation. This resulted in initial measures and changes to the original plans. Some of the storage tanks will be repositioned and the existing hydraulic integration will also be adapted. However, the need for even more accurate simulations and a holistic approach became clear. The expansion of the solar system and new storage tanks near the solar plant have been scheduled for 2022. The next step will include a comprehensive analysis of the various solutions in order to evaluate further storage facilities and their management. This analysis will be done in early summer of 2022 and also stake out the possibilities of a 100% renewable supply.

Keywords: Solar, District Heating, Storage, Biomass, Operation Strategies,

PhD student at Halmstad University passionate for District Heating and its ability to decarbonise the heat supply and attain Europe's energy independence in a cost-effective fashion

Viability of district heating networks in temperate climates: Benefits and barriers of ultra-low cold and warm temperature networks

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The decarbonization of the heat supply and the achievement of a higher energy security calls for the substitution of conventional fossil fuel boilers by other means of heat supply. In dense urban areas, where the pipe network cost is proportionally lower, district heating can be an attractive solution for this goal. If there is a possibility to recover heat that would otherwise be wasted or produce renewable heat centrally in a more economic manner, this can be a very cost-effective solution for decarbonising the heat supply. Networks for district heating have traditionally distributed heat at a temperature sufficiently high to virtually all consumers. In cold district networks , the network is maintained at close to ambient temperature (10-30°C), and require the heat to be boosted at the consumer level. Cold networks have drawn plenty of research attention thanks to several advantages such as their capacity to provide with the same network both heating and cooling or using more economic piping. Nonetheless, comparisons between the two technologies have been seldom performed in the literature. This study has aimed to fill this gap and has drawn an economic comparison between these two solutions in a case study for the city of Bilbao, which presents a mild oceanic climate but features a very dense urban fabric

Keywords: Warm Network, Cold Network, Distribution Technology, Heat Density

Uffe has 20 years of experience in district energy where he has implemented intelligent solutions that combines heating and cooling, sector coupling and storage with very little carbon footprint. In his current role at Grundfos, he is responsible for developing the future sustainable solutions.

How to effectively convert gas area into district heating

Uffe Schleiss, Grundfos

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In Denmark and Europe we are facing major expansions of the district heating networks where it is possible to convert existing gas areas.
Not only is there a severe shortage of contractors, we also see delivery issues on pipes and technical installations.
To avoid upgrading their existing grids to be able to supply these areas, one can boost the system pressure in strategic places. This will significantly minimize construction costs
However, one should also explore the possibility of delivering lower supply temperatures to new areas, which may minimize the need for capacity increase (low temperature zones).
By lowering the supply temperature it opens up possibilities for usage of renewable energy sources, such as surplus heat, sewage and ground water.
Even in areas where it is not profitable to lay out a distribution line, a collective solution could be found. Possibly cold district heating or low temperature zone with a heat pump.
Although there is a lot of focus on gas conversions at the moment, it is really important to remember the optimization of the system. Typically with extensions, the existing measuring points of the system become obsolete, therefore new ones are needed. But it can be difficult to find the right place to have a measuring point. New types of measure points are both precise and mobile, so no power connection is required and the measure point can be moved around, which makes it possible to always have it in the right place.
Furthermore, the solutions that will be presented are demand-driven and digitally enabled, which secures the additional saving in the district heating grids.

Keywords: Low temperature, district heating, digital, demand-driven, pressure distribution, heat pumps, renewables, surplus energy

Former analyst in IEA, Green Energy and PlanEnergi. PhD from DTU Management where he is currently a postdoc. Focus is on integration and flexibility in the interface to the electricity grid. His research includes analyses of regulation of district energy in Nordics, Baltics and US.

Switching from natural gas to district heating: Measured impacts on household energy use

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The switch from natural gas to other heat sources in households takes an increasingly important role in the efforts towards increased decarbonisation and security of supply. While this is undoubtedly important, there is limited knowledge on the subsequent household energy-related impacts. Does the supply-switch entail increased or decreased energy consumption? In other words, we ask if there is a rebound effect of switching to district heating, like what is seen within energy efficiency measures.

Based in FIE-data, a Danish registry of building-level energy consumption, we statistically analyse what happens when household switch from natural gas to district heating.

By the time of abstract-submission, results are in the making. We hypothesise that there is a small increase in energy consumption due to the aforementioned rebound effect.

While the results are for Denmark, there is a broad applicability of the findings. Firstly, Denmark stands out in terms of data availability. In other words, a similar study on large-scale datasets may not be possible in other countries. Second, we assume that the general tendencies identified in Denmark may apply equally well in other countries.

Any such changes identified regarding switch from natural gas are important, since energy system modelling and similar analyses should take into account increases and decreases of energy consumption, as part of the switch from natural gas.

Keywords: District heating, natural gas, fuel switching, energy consumption, statistics

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.

Impacts of global warming and building renovation on the heating energy demand and district heating capacity: Case of the city of Riga

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Changes in weather conditions due to global warming affect the energy demand of buildings, resulting also in changes in the installed heat capacity in district heating (DH) systems. The study provides a methodology to support decision-making for decarbonization scenarios of cities by developing a sustainable 4th generation district heating (4GDH) system combined with renovation of existing building stock and development of newly built areas in the long-term perspective (till 2050). Several scenarios are proposed where a multi-generative DH system is assessed by implementation of industrial heat pumps, solar systems, and low-temperature regime into an existing DH system that currently is based on biomass and natural gas combustion technologies. Changes in the heating load of a DH system due to improvement of building energy efficiency are studied in combination with three weather scenarios – low RCP2.6 (Representative Concentration Pathway); medium – RCP6.6, and high – RCP8.5. The developed scenarios consider the integration of heat energy produced by prosumers in local energy communities. Heat demand model combined with techno-economic model estimates the potential of climate change impacts on the DH system of the Riga city. The research considers the influence of the energy carriers' price (fuel, electricity, etc.) on economic parameters, feasibility and environmental performance of the DH system and investigates the balance point between investment at the source and heat consumers' side. A sustainability assessment was performed for the interconnected climate change, heat demand of buildings, and energy production based on the 4GDH technologies. The interaction of global warming, buildings heating energy demand and installed capacity of the DH system, that make up urban environmental nexus, was identified by levelized investment approach. The research results show that building renovation process has significantly higher impact on heat demand compared to influence of temperature changes due to global warming.

Keywords: District heating, 4GDH, climate change, climate adaptation, techno-economic analysis, building energy efficiency, building renovation, heating energy, sustainability assessment

Dr.hab.sc. ing. Dagnija Blumberga specializes in energy production, renewable energy sources, climate change, environmental technologies. She is the author of more than 450 scientific articles. She has experience in more than 10 international projects as a researcher, expert and project leader.

Harmonisation of waste heat in district heating

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A European Union directive has defined the necessity to promote waste heat integration in district heating (DH) systems. Waste heat flows can be divided into two large groups: high and low-temperature heat sources. Looking from the heat balance perspective, it is possible to obtain larger volumes of thermal energy from low-temperature waste heat sources. Still, their cost will most often be higher than for high-temperature sources.

To recover thermal energy, its quality, and the possibilities of using it in the DH system is essential. The wide range of engineering solutions includes a direct connection to the DH system and the integration of low-quality heat as the energy source of the DH system. One of the technological solutions for waste heat integration is related to heat pumps which could increase the temperature level of recovered heat. The heat pumps have an essential role in surplus renewable power utilisation when focusing on future smart energy systems. A large-scale electrically driven heat pump is one of the most effective solutions for cross-sector integration in the low-temperature range. With cheap thermal energy storage, power-to-heat technologies allow DH systems to accommodate more intermittent renewable energy than alternatives.

From the point of view of the DH network operator, waste heat should be cheaper than the marginal production costs of existing supply units. Therefore, purchasing waste heat from external sources can significantly benefit DH network operators. With the purchase of waste heat, the DH network operator can reduce production costs by replacing existing and more expensive peak load generation. The waste heat tariff depends on the overall power price due to the heat transferring costs and heat pump use in low potential heat. Therefore, careful assessment is necessary to evaluate the use of waste heat in different power and heat price, operation, and investment cost levels.

The article discusses the economic and environmental analysis of four different engineering configurations, looking for optimal solutions depending on various parameters, temperatures, volumes of thermal energy supply, investments, operating costs, internal profits and tariffs.

Keywords: district heating, waste heat, low temperature heat sources

Ali Kök is a research associate and Ph.D. candidate in Energy Economics Group (EEG), TU Wien. His research focuses on energy system modeling to assess decarbonization pathways of the heating and cooling sector.

The distance between industrial sites and district heating grids as a driver of the economic viability of waste heat integration

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Industrial waste heat recovery has a great potential to contribute to a sustainable district heating (DH) sector. Consideration of spatial dimension is crucial in implementing waste heat recovery practices. In this paper, we analyze the impact of distance between industrial waste heat sources and DH grids or heat demand points on the economic viability of DH grids and the size of the analysis area on the level of detail for the analysis. For this purpose, we developed a network optimization model that optimizes the topology of a DH network based on heat sources and sinks, analysis area, and various economic and environmental variables such as investment costs and ambient/ground temperature levels. The road network in the analysis area is obtained via Open Street Map. Adding an existing DH grid network into the analysis area is also possible. The problem is solved using mixed-integer linear programming, which is decomposed into two steps to decrease complexity: routing and thermal capacity optimization. After the optimization, heat losses and network costs are calculated. The results are the individual and cumulated pipe lengths, losses, installed pipe capacities, the network costs between source-sink pairs, and visually represented network solution. A separate techno-economic optimization (TEO) model is used to incorporate the time dimension and dispatch of technologies. The TEO model determines the least-cost capacities and operation of technologies considering temporal variations of excess heat availability and heat demands. In the paper, we will apply the model to a case study through varying settings like the size of the analysis area, the number of heat sources and sinks, source and sink potentials, or cost parameters and identify the impact of these parameters on the economic viability of the DH grid and the identification of priority areas for intervention. Also, conclusions regarding prioritization in terms of timing for intervention will be derived. These results could support the industry sector along with decision- and policy-makers, local/regional authorities, or governments to assess the potential for DH investments in a given region/network as an option to improve energy efficiency and contribute to their decarbonization targets.

Keywords: industrial waste heat recovery, district heating, DH grid, network optimization, spatial analysis

Henrique is a research fellow at London South Bank University, where he investigates how the potential to recover waste heat from several sources in urban areas can be unlocked by district heating and become a key technology in the transition towards a low carbon and cost-effective energy system.

Heat Recovery Opportunities from Electrical Substations

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Electrical substations are key pieces of infrastructure that are used to step up and down voltages for the transmission and distribution of electricity. The transformation of voltages in substations leads to energy losses in the form of heat, which could be harvested by district heating networks in order to supply low carbon heat to nearby buildings. This opportunity is expected to be even greater in future years as the electrification of heat supply leads to an increase in the distribution capacity of the electricity grid. At first, this paper investigates the potential availability of waste heat from electrical transformers above 60 MVA for transmission and distribution network operators in England, Northern Ireland and Wales, with a total thermal energy output of 4.0 TWh per annum being estimated. Possible configurations for recovering waste heat from transformers are then presented, and these are used to assess the benefits that could be obtained against conventional heating technologies based on the annual loading profile of a bulk supply point (BSP) transformer. Although the case study is based in the UK, the methodology hereby described can also be applied to evaluate the potential for heat recovery transformers in other countries.

Keywords: Waste heat, transformers, substations, electricity distribution, heat pumps, district heating

Kertu Lepiksaar is a PhD student in Tallinn University of Technology, in research group of smart district heating systems and integrated assessment analysis of green house gases emissions.

Utilisation of Sewage Water Heat in District Heating and the Impact on the Water Treatment Process

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Using sewage water heat in district heating with large-scale heat pumps is a common practice, as sewage water is a particularly good source of heat due to its sufficiently high temperatures. Typically, when the sewage water first enters the water treatment plant, the flow temperature is 11-15°C in winter and above 15°C in summer, which is excellent for use as a low-temperature heat source for heat pumps. The waste heat can be used after the treatment process when the flow temperature is around 9-10°C. In the sewage water treatment process, there are many stages with higher temperatures where the waste heat could be used for heat pumps, but in some cases, it would reduce the efficiency of the water treatment process. Water temperature is a very important parameter when it comes to biological treatment processes. It affects the settling capacity, the accumulation of floc, the diversity of microorganisms in the biomass, and other qualities of activated sludge. Furthermore, if the temperature drops too low, the biological treatment process stops, which can lead to pollution of local aquatic ecosystems and result in pollution charges for the operator. The stages of the treatment process with available waste heat should be explored further. This study thoroughly analyses the water treatment process to determine the optimal solution for using sewage water waste heat in district heating and indicates the possible impact of using waste heat on the water treatment process. This study uses data from the Tallinn sewage water treatment plant data as an example and estimates the amount of usable waste heat during the water treatment process.

Keywords: biological treatment, district heating, heat pumps, sewage water, waste heat

Ingo Leusbrock is head of "Cities and Networks" department at AEE INTEC in Gleisdorf, Austria. His research interests include modeling, simulation and implementation of energy systems with focus on district heating & cooling, holistic energy system analyses, and innovative energy supply concepts.

How to combine district heating and waste water treatment plants? A demonstration example from Gleisdorf, Austria

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Within the concept development of future heat demand scenarios strategic development plans including all relevant and available local heat sources were conducted for the DH network of Gleisdorf as part of the Austrian flagship project ThermaFLEX. The future concept focusses on the so-called “Virtual Heating Plant” control approach, incorporating technical measures combined with advanced control for central and decentral heat supply as innovative elements. The sector coupling of the two infrastructures 1) district heating and 2) waste water treatment plant (WWTP) was identified as a central element and is the aimed starting measure for the implementation of an “Energy Hub” at the WWTP site. The concept includes a modular heat pump for the utilization of low temperature heat from waste water, a biogas booster heating unit and a DH connection pipeline (~ 1,100 m) to the existing heating network. The concept provides thermal energy from the purified waste water (as a heat source for a developed heat pump concept) and biogas from the anaerobic digestion step. The total energy produced can be fed into the district heating network over the whole year. In the first expansion stage, a heat pump concept with approx. 500 kW heating capacity will be implemented producing nearly 4,000 MWh heat and results in CO2 savings of around 1,000 tons compared to the use of natural gas. Another important positive effect in terms of efficient use of resources and circular economy is the complete energetic utilization of the biogas from the WWTP by an intelligent control system and flare of biogas (excess) will be avoided.
The sector coupling as well as subsequently Energy Hub concept is supported by all relevant stakeholders (City of Gleisdorf, operator from DH network and WWTP, etc.) and paves the way for the integration of various further implementation steps which are necessary to cover the continuous growing heat demand of approx. 500 kWth/a in the DH network. Next to the WWTP concept and the ideas for the Energy Hub, we will present results of a techno-economical evaluation of all steps including a life-cycle analysis.

Keywords: District heating, sector coupling, low temperature waste heat utilization, waste water treatment plant

Nicolas Marx has been working at the AIT since December 2022, in the field „District Heating and Cooling“. During his master studies of industrial energy technologies, which he finished in 2021, he gained his first professional experiences in the solar thermal industry.

Decarbonizing the heating supply via regional district heating networks – Best Practice Analysis and Status-Quo for a case study in Tyrol (Austria)

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The “Heat Highway” project is part of the NEFI model region that positions energy intensive and manufacturing industries and their decarbonization in the center of a long-term innovation process to boost technological development. The utilization of waste heat is a key pillar for decarbonizing district heating systems. While the electricity transmission grid is connecting generation and consumption units, options for the long-distance heat transmission and interregional exchange are limited. Heat Highway thus investigates interregional heat transmission networks (HTN), which connect multiple industrial waste heat and other sustainable sources, one or more district heating networks, industrial process heat sinks, and storages. These interregional networks connect urban consumption centers and waste heat-intensive industrial sites and, in doing so, traverse areas with further heat sources and sinks.

To better understand the barriers and opportunities for HTNs, an analysis was conducted among national and international best practice examples including interviews with stakeholders. The focus was on general working principles, successful concepts, promising situations, financing, contract set-up, legal aspects and social issues. A total of 38 systems were identified, 10 of which were classified as HTNs. The results of the investigation were used to conduct a SWOT analysis, depicting the strengths, weaknesses, opportunities and threats.

Within the project, the implementation of HTNs in the different regions in Austria is assessed to ensure replicability. One of these regions is the Inn river valley in Tyrol, for which potential heat sinks and sources for the implementation of a HTN were identified by utilizing publicly available databases and reports. A focus was placed on the region east of the city of Wattens to identify possible extensions of the existing HTN between Wattens and Innsbruck. Demand nodes were defined on a municipality level and compared to the current heat production / industrial waste heat potentials to find possible surpluses. With all available data mapped, three focus areas were defined. Between the defined areas are stretches of sparsely populated land, where an economic analysis will show whether a connection between the areas is feasible.

Keywords: Future District Heating, Waste Heat Sources, 4th Generation DH, Heat Transmission Networks

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

Identifying locations for optimal heat extraction from city waste water

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The utilisation of waste heat is a key measure towards decarbonisation of district heating systems. District heating networks can act as a buffer between supply and demand, not only bringing together various different load profiles and thus building up a more even heat supply or demand but also as a thermal bus connecting widely distributed heat sources and sinks. However, the identification and evaluation of available waste heat sources, including waste heat from small industries, service sectors and sewage systems, is still challenging. The project MEMPHIS 2.0 funded by the IEA Implementing Agreement on District Heating and Cooling including Combined Heat and Power within the Annex XIII work programme develops the methodology of the previous MEMPHIS project further. Within the follow-up project, the previously developed quantification, qualification and spatial allocation of waste heat potential within city limits shall also cover economical questions and be applied to further cities. Furthermore, the research shall answer the following questions: What is the composition of the sources of the calculated wastewater flows, and how does this affect the profile of the sewer discharge? How large is the potential for waste heat from a sewage system within the city limits if optimal heat extraction is realised?
By combining open data with key metrics, temperature profiles and heat losses in the sewage system and formulating an optimization model, the methodology finds, firstly, the most likely route taken by the wastewater to the wastewater treatment plant. Secondly, it determines the various sources, load profiles and temperature levels of the wastewater flow in a time-resolved manner. Thirdly, it shows locations for the optimized extraction of waste heat from the sewage

system to extract as much thermal energy as possible from the wastewater network within the city limits. A top-down approach helps to validate the modelled wastewater flow by utilising real wastewater quantities at the outlet of the wastewater treatment plant.
The methodology is applied to more than 100 cities in Germany, 3 Italian cities and 2 Austrian cities. The findings are visualised in http://cities.ait.ac.at/uilab/udb/home/memphis, with options to create tailor-made assessment reports.

Keywords: waste heat, wastewater system, sewage water, waste heat utilisation, district heating system, open data

Stefan Reuter has a Master's degree in “Physical Energy and Measurement Engineering” from the Vienna University of Technology. He works at AIT and is focusing on the decarbonization of industry, the integration of waste heat from industry into heating markets and renewable gases.

Techno-economic assessment of waste heat utilization: Design and implementation of a rapid assessment tool

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The integration of waste heat into district heating networks is a key measure towards the decarbonization of the heating sector. However, the identification and evaluation of available waste heat sources at the local level is challenging. As the industrial sector is in an ongoing process of decarbonization, associated process changes may impact the availability of waste heat. Additionally, due to this transformation process new waste heat sources are expected to emerge. Based on a methodology to identify and locate waste heat potentials from industrial and service sectors [1], the “MEMPHIS 2.0” project aims to include missing information about the techno-economic potential, thus strengthening the waste heat utilisation.

Different scenarios for the decarbonization of industrial sectors were assessed to derive implications on the future availability and quality of waste heat from these sectors. Further on, future waste heat sources with increasing potentials, including data centres and electrolyzers, were identified and analysed based on literature research. A methodology for the techno-economic assessment of the utilisation of these waste heat sources was developed based on the calculated waste heat potentials. For this purpose, detailed information on sectors with low-temperature waste heat was collected and the temporal availability of waste heat sources was analysed via sector-specific load profiles.

The results of the improved methodological approach were integrated in an interactive online tool (Waste Heat Explorer) where locations and potentials of waste heat sources are included. With the implementation of a rapid techno-economic assessment, stakeholders can use this platform to obtain an initial estimate of the feasibility of waste heat utilisation after entering basic information about their heat demand. The inclusion of prospective waste heat potentials for a decarbonized industry aims to depict a realistic assessment for the utilisation of waste heat within the next decades. Through the opportunity to match waste heat producers and possible users, the successful utilisation of waste heat is fostered.

[1] https://www.iea-dhc.org/the-research/annexes/annex-xii/annex-xii-project-02

Keywords: waste heat integration, future waste heat sources, mapping of waste heat potentials, techno-economic assessment

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.

Analysis of Enhanced Geothermal System Development Scenarios for District Heating and Cooling of the Göttingen University Campus

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Bernd Leiss, Geoscience Centre of Georg-August-Universität Göttingen;
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The huge energy potential of Enhanced Geothermal Systems (EGS) makes them perspective sources of non-intermittent renewable energy for the future. This paper focuses on potential scenarios of EGS development in a locally and in regard to geothermal exploration , poorly known geological setting—the Variscan fold-and-thrust belt—for district heating and cooling of the Göttingen University campus. On average, the considered single EGS doublet might cover about 20% of the heat demand and 6% of the cooling demand of the campus. The levelized cost of heat (LCOH), net present value (NPV) and CO2 abatement cost were evaluated with the help of a spreadsheet-based model. As a result, the majority of scenarios of the reference case are currently not profitable. Based on the analysis, EGS heat output should be at least 11 MWth (with the brine flow rate being 40 l/s and wellhead temperature being 140 °C) for a potentially profitable project. These parameters can be a target for subsurface investigation, reservoir modeling and hydraulic stimulation at a later stage. However, sensitivity analysis presented some conditions that yield better results. Among the most influential parameters on the outcome are subsidies for research wells, proximity to the campus, temperature drawdown and drilling costs. If realized, the EGS project in Göttingen might save up to 18,100 t CO2 (34%) annually.

Keywords: deep geothermal energy, EGS, Variscan fold-and-thrust belt, district heating and cooling,
economic indicators, CO2 abatement cost, sensitivity analysis

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 modeling of heating networks.

Analysis to determine the potential of waste water heat to supply urban areas

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Currently, 83 % of the district heating systems in Germany are provided by mostly fossil-fuelled CHP plants. With regard to the ambitious goals for decarbonising the German energy system, the heating sector will rely on the use of solar energy, ambient heat as well as waste heat. Great potential is offered by district heating in connection with sector coupling through power-to-heat (PtH) technologies. In particular, the use of large heat pumps enables the reduction of final energy consumption via the seasonal performance factor. More than a third of the large heat pumps with a capacity of more than 1 MWth used in Europe, Norway and Switzerland use wastewater as a heat source. In Germany, the use of wastewater heat was limited to supplying a few buildings until 2016. Only in the last few years have some projects for supplying urban areas gone into planning.

This study aims to investigate how wastewater heat can contribute to the decarbonisation of urban areas and to determine the technical and economic boundaries of wastewater heat utilisation by means of large-scale heat pumps. For this purpose, a Germany-wide study is to be conducted to link the heat demand in urban areas with the locally available wastewater heat potential.

The final result shows that the temperature difference between the heat source and the heat sink must not exceed 45 K in order to ensure an economic operation of the wastewater heat utilisation plants.

Keywords: Wastewater heat potential, district heating, heat demand

Energy Engineer and PhD student in Energy and Nuclear Science and Technology at Politecnico di Milano. She works on projects about the evaluation of technical and economic potential of low-temperature district heating, through the spatial and temporal analysis of excess heat sources and heat demand

An industrial waste heat recovery atlas: identification of recovery coefficients and parametrization of storage size according to different DH demand

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Alice Dénarié, Politecnico di Milano
Nicola Cesare Di Nunzio, Politecnico di Milano
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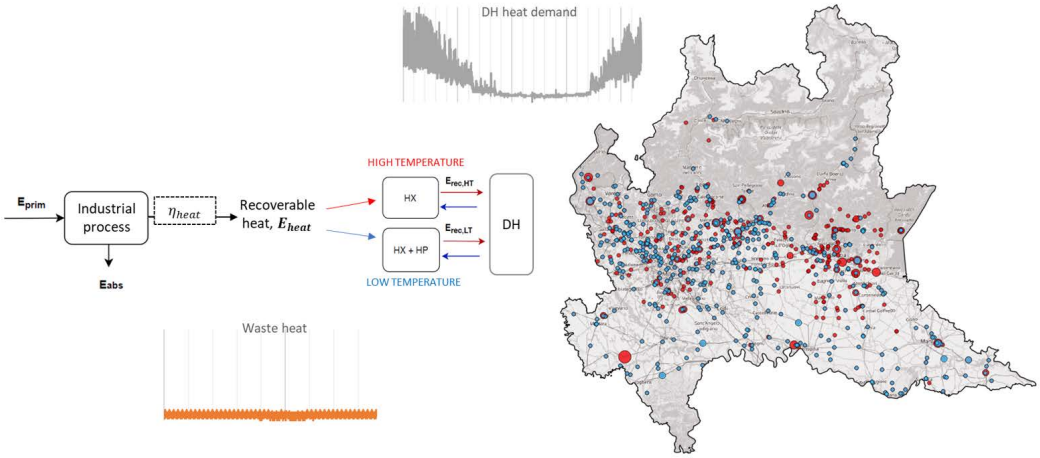
According to 2018 Eurostat data, industry accounts for 26% of the final energy consumption in EU. An interesting fraction of this energy is not converted into useful work and is released in the environment in the form of exhausts or effluents which are recoverable for various processes inside the industrial facility itself or externally, through district heating. The recovery potential is highly dependent on the amount of energy released and its temperature level and it depends on spatiotemporal constraints: the industry should be at a reasonable distance from the district heating network and there should be a supply-demand temporal correspondence. The satisfaction of this latter constraint can be made easier by means of heat storage systems.
This work presents a regional atlas of heat recovery potential from industries in Lombardia, the most populated Italian region, based on available specific data and literature. IWH results to be 20.7 TWh/year, corresponding to 30% of the heating demand. The temporal constraints are expected to introduce a 60% reduction, that can be counteracted by the introduction of heat storages.
The steps followed in the definition of this map are: i) identification of the available waste heat sources with distinction between the manufacturing sectors, ii) estimation of the theoretical recovery potential through the application of recovery coefficients derived from eight different methodologies found in literature, differentiated according to the production processes and their temperature levels, iii) estimation of the technical recovery potential by considering the temporal matching between source and demand, iv) integration of heat storage systems and assessment of the associated benefits, v) economic analysis to assess the feasibility and the competitiveness of IWH recovery.

The added value of this work lies in the search, in each step leading to the resulting definition of recoverable waste heat, for correlations and parameterizations that can make the methodology generalizable and applicable in different contexts.

This work has been financed by the Research Fund for the Italian Electrical System in compliance with the Decree of Minister of Economic Development April 16, 2018.

Keywords: Waste heat atlas, Waste heat recovery, Industry, Spatiotemporal analysis, Economic analysis, Temperature levels, Recovery coefficients, Thermal energy storage (TES) systems, Parametric analysis



Dietrich Schmidt is head of Department Thermal Energy System Technology and works in the field of district heating, energy utilization in buildings, energy supply structures of buildings and communities. He coordinated of a number of projects within the frame of the International Energy Agency.

DIGITALISATION IN DISTRICT HEATING SUPPLY – WITH DATA TO OPTIMISED SYSTEMS AND NEW BUSINESS OPPORTUNITIES

Dietrich Schmidt, Fraunhofer IEE; Michele Tunzi, DTU; Edmund Widl, AIT; Markus Gölles, BEST; Dirk Vanhoudt, VITO

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District heating and cooling (DHC) networks are traditionally operated with a limited number of sensors and actuators to secure the required supply and to optimize economics based on a given high ecologic performance. An optimised heat generation and overall network operation is possible with more information on the demand and flexibility options. An increased deployment of information and communication technologies enables better network management based on real time measurement data and the integration of new digital business processes. For a further development, the promotion of opportunities for the integration of digital processes into DHC systems is required and the role of digitalisation for different parts within district heating and cooling systems needs to be clarified. Digital technologies are expected 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, additional challenges need to be tackled, such as data security and privacy as well as questions about data ownership. The presentation, the paper presents and discusses the first results from the 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".

https://www.iea-dhc.org/the-research/annexes/2018-2024-annex-ts4

Keywords: digitalization of district heating; operation and maintenance; business processes and models

Michele Tunzi main research interests focus on the 4th Generation District Heating and Cooling, HVAC systems and digitalization of the demand side. He developed independent research work and established solid collaborations with academia and industry, coordinating national and international projects

Digitalization of Demand side as the enabler for the transition towards 4th Generation district heating (4GDH)

Michele Tunzi, Svend Svendsen

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The role of the digitalization of the demand side increased significantly in Europe in the last few years. This was mainly due to the impulse of the European Energy Efficiency Directive (EED 2012/2018), binding member states to have all energy meters and submeters remotely readable by January 2027. In several cases, buildings and end-users have been the limiting factor in lowering operating temperatures in district heating networks due to poor control and operation. Based on existing Danish case studies connected to the local district heating networks, it was documented that existing buildings can be comfortably heated with supply and return temperatures of 50/30 °C at 0 °C outdoor temperature. The improved heating system operation was achieved with the innovative use of data from the heat cost allocators, energy meters, and temperature sensors, representing a step forward in the transition toward 4GDH. This was possible without any deep energy renovation in the building or investments, yet just securing correct control and operation of the heating systems. Further results showed the role of remote connected digital devices in pinpointing heating system faults and secure, after servicing the heating system, return temperature of 35 °C or below in multifamily buildings. These results summarize some of the activities related to the digitalization of the demand side that is part of the IEA DHC Annex TS4 on Digitalization of District Heating Systems – Optimized Operation and Maintenance of District Heating and Cooling Systems via Digital Process Management.

Keywords: digitalization of demand-side, district heat networks, low-temperatures, existing buildings, heat cost allocators, energy meters, temperature sensors

Pakdad is a research associate in the field of Infrastructure Engineering. The topic that he focuses is "Predictive Maintenance" and he develop models to adopt this technique in the district heating/cooling systems. What he mainly does is to dig the past data to predict the future.

A Combi-Model for Failure Prediction of the Pre-Insulated Pipes in District Heating/Cooling Networks

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District Heating/Cooling networks are playing as a fundamental energy carrier in many countries now a days and because of their high efficiency and robustness, more countries are tending to adopt this technology and the ones who already have it are expanding their networks. Keep the system up and running without interruption is one of the important topics as system reliability that in various industries have been questioned and studied. The system reliability in most cases is entangled with maintenance. However, the pre-insulated bounded pipes make it easy to spread the DHC systems, the composition of the steel medium pipe, rigid polyurethane foam (PUR), and the polyethylene (PE) casing cancels the deterministic approaches for failure prediction due to their complex behaviour. In this research, a new combi-model for failure prediction has been developed to improve system reliability and facilitate the asset management strategies. This model combines the deterministic approaches such as fatigue analysis, foam thermo-oxidation with the damage statistic of the DHC network for a multi-variant analysis on ageing mechanisms and failure prediction. The model uses the loading history to calculate, analyze and predict the failure of the pipe. The predictive maintenance approach that is employed in the model could reduce the maintenance costs and introduce a new asset management strategy. Various machine-learning techniques that are used in the model not only help to improve the prediction rates incrementally, but to be easily adopted and extend its operation in various industry 4.0 applications such as digital twins, IoT, live data analysis, etc.

Keywords: District Heating/Cooling, Failure Prediction, Predictive Maintenance, Pre-Insulated Pipes, Asset Management

Jakob Fester holds a PhD in Physics from Aarhus University and is currently employed as a consultant at the Danish Technological Institute in the Energy and Climate division. He works with development and demonstration projects within the cross field of digitalization, metrology and district heating

Algorithms for assessing the condition of district heating service pipes exploiting GIS data, data from smart meters and soil temperature measurements

Jakob Fester, Danish Technological Institute; Peter Friis Østergaard, Danish Technological Institute; Brian Kongsgaard Nielsen, Grundfos A/S; Fredrik Bentsen, VERDO

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District heating (DH) networks accommodate 30.000 kilometers of double pipe in Denmark and constitute the main asset of the DH suppliers. Since many of the pipes are older than 20 years and of unknown condition, there is a strong demand for better and more detailed knowledge about the present state and development of every pipe to ensure a cost-effective ongoing renovation and a reduced loss of water and energy. For this purpose, the massive roll-out of smart meters which has taken place in the district heating sector over the recent years provides a unique opportunity since it offers access to large and growing databases of hourly resolved temperature and flow data from the customer end points.

In this study, we developed a new method and algorithms to calculate the heat loss of service pipes indicative of their general physical condition, and which can be used for leakage and fracture surveillance. In a first step, GIS data is processed and formatted from the raw coordinates of every pipe segment to an output that relates the individual positions of service pipes to each other in groups. In a second step, smart meter data and soil moisture measurements are combined in a physical model of the service pipes. On this basis, a data-driven iterative algorithm calculates and updates the heat loss. Finally, we furthermore estimate values for the absolute and intercomparable heat transmission coefficients in a post analysis step, considering a grouping strategy of the hourly readings in batches.

The method and algorithms were tested on real GIS and smart meter data from local geographical areas supplied by two different Danish DH companies on scales ranging from 17 to more than thousand service pipes. The results were validated by comparison to data from additionally installed measurement points in the pipe grid, high resolution data from a test area in Randers (DK) and actual registrations and repair of fractures in the analyzed pipe network of Bording (DK).

Keywords: District heating pipe networks, Digital tools, Smart meter data, GIS-data, Data-driven algorithms, Big data, Heat loss calculation, Asset Management and Renovation Planning

Ralf-Roman Schmidt is working at AIT since 2009, where he is responsible for the development and management of projects in the field of district heating and integrated energy systems. He holds key positions in international networks and received a PhD in the field of thermo-fluid dynamics in 2013

The AIT DigitalEnergyTestbed: An open test environment for digitalization solutions for integrated district heating networks

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Digitalization is one of the key enablers for district heating systems to optimise their performance in terms of efficiency and integration of renewables as well as for end user involvement. On the other hand, sector coupling is believed to play an increasingly important role, and digitalization would be a key technology for overcoming the complexity of a fully integrated energy systems. As a consequence, an increasing number of digital solutions for the integrated operation of different domains have appeared recently, e.g. controllers and/ or optimizers from E.ON (ectocloud), Utilifeed, FlexHarvester, NODA or Gradyent. However, the development, adaptation, and integration of such digital solutions is complex and involves considerable time and cost expenditure. Furthermore, the transferability and comparability of results can be limited.

This contribution presents the concept, use cases and the initial test results of the AIT DigitalEnergyTestbed, an open test environment for the evaluation, (further) development and integration of digitalization solutions for integrated district heating networks . The testbed considers different energy domains (electricity, heating & cooling, possibly gas), and it integrates different types of technologies (from simulation to hardware).

Relevant use cases for the AIT DigitalEnergyTestbed include:

- Supporting the design and operation of innovative systems combining components such as heat pumps, batteries, electric boilers, thermal storages, and fluctuating renewables (e.g., wind or PV via direct power lines).
- Supporting the development and validation of system-level software such as IoT platforms and their applications. This includes the development and validation of digital twins (based on analytical and/or data-driven models) for predictive simulation and controls in integrated energy systems.

The AIT DigitalEnergyTestbed is based on Lablink, an open-source middleware for lab experiments, using open standards for interfacing automation systems (OPC UA) and simulation tools (FMI). As a proof-of-concept, a testbed prototype has been implemented around an existing DH substation test stand.

Keywords: Digitalization, digitization, district heating, laboratory infrastructure, test stand, simulation, modelling, integration

Dr.-Ing. Anna Kallert is head of the department "Thermal Energy System Technology" at the Fraunhofer Institute for Energy Economics and Energy System Technology in Kassel, Germany. Her work focuses on the energetic, ecological and economic analysis of thermal energy supply solutions.

IEA EBC Annex 84: Demand Management of Buildings in Thermal Networks – Case Studies including DH and DC Systems

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District heating and cooling (DHC) is known as a key technology for the (cost-) efficient integration of renewable energy and waste heat sources in our energy systems. However, a high number of buildings connected to DHC have faulty operation leading to an unnecessary high energy demand and an inefficient operation of DHC systems.
In most cases, the optimization of DHC often focuses on the system side and does not integrate the secondary side. Solving the challenge of demand side management (DSM) is mainly technological, yet the success of new solutions is also hinged on building users. Resulting the adaptation of the new concepts requires mutual engagement, acceptance and co-operation of end-users, engineers, facility managers and utility operators. The process is known as very time-consuming and risk-averse. The key to overcome these barriers is access to compelling evidence of existing successful installations that tangibly demonstrate how the technology can be implemented, operated and risks managed.
Within the IEA EBC Annex 84 realised energy system concepts as well as planned or designed systems are identified and visualised. To provide and compare DSM design solutions for both new and existing building as well as laboratory systems (test facilities) and virtual platforms (software models) are classified and evaluated.
From currently about 20 demonstrators included in the EBC Annex 84 a selection of 7 cases are analysed in detail with regard to which elements of new knowledge they can generate. As part of the contribution, the interim results of the collaborative research work on the analysis of case studies within of the ongoing IEA EBC Annex 84 on Demand Management of Buildings in Thermal Networks are presented and discussed. The collected lessons-learned from case studies of technologies, buildings or DHC communities will help to facilitate and to improve DSM in DHC. Furthermore, the engagement, the acceptance and the co-operation of the building users and key players in the energy supply can be promoted.

Keywords: district heating and cooling, demand side management, case studies, innovative heat supply

Anna has scientific experience in design and performance evaluation of high performance, flexible buildings; integration of buildings in smart energy systems (B2G) with focus on power grids and DH networks; measurements and modelling of domestic energy loads; Life Cycle Cost analysis.

IEA EBC Annex 84: Demand Management of Buildings in Thermal Networks

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In 2019, space heating and domestic hot water preparation corresponded to 12% of the global energy and the process-related CO2 emissions. Space cooling accounted for additional 3%. The collective systems for heating and cooling of buildings, known as district heating and cooling (DHC) networks, is a vital solution to meet the residential and commercial heating and/or cooling demand in a sustainable manner in dense populated areas, where installation of individual heat pumps is impractical. Existing DHC networks are also considered to play a strategic role in the successful decarbonisation and smart green transition of future energy systems (e.g. as energy hub between different energy vectors).

The transition from stable fossil fuels to fluctuating renewable energy sources requires a change in operation of the DHC networks both at the primary and secondary side. The well-known and applied concept of demand side management in electricity grids can also be used in DHC systems to enhance and foster the decarbonisation process of the DHC networks (e.g. by reducing peak loads, providing flexible thermal storage, and allowing for new business models).

The aim of IEA EBC Annex 84 is to provide a comprehensive knowledge and tools for proactive demand management of buildings in DHC networks. The work of the Annex will investigate both the social and technical challenges and how these can be overcome for various building typologies, climate zones and local conditions as well as how digitalisation of heating/cooling demand facilitates the demand management activation.

In order to achieve the overarching Annex aim, the Annex has following specific objectives:

- Provide knowledge on partners/actors involved in the energy chain and on collaboration models/instruments.
- Classify, evaluate and provide design solutions for new and existing building heating and cooling installations.

- Develop methods and tools to utilize data from monitoring equipment (e.g. smart meters, sensors) for real-time data modelling of thermal storage potential in buildings and urban districts.
- Provide knowledge from and drive adaptation and visualization of Annex results through case studies.

Participants: Austria, Belgium, Denmark, Germany, Italy, Netherlands, Singapore, Spain, Turkey, UK

Keywords: Demand management, district heating, district cooling, collaboration models, buildings as thermal storage, hardware, software, demo cases

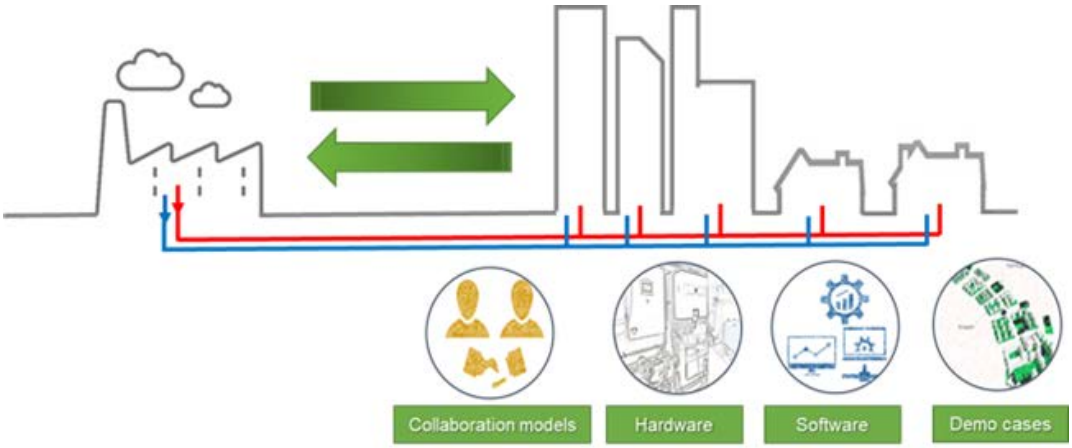

Fig 1. IEA EBC Annex 84 concept and focus areas

Tijs Van Oevelen holds a Master and PhD in Mechanical Engineering. Tijs is a researcher in the Energy Technology unit of VITO, where he joined the Thermal Energy Systems team in 2017. His current work focuses on smart thermal energy systems through digitalization and operational optimization.

Testing a smart controller for district heating systems : Results from an Italian case study in the TEMPO project

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The aim of the TEMPO project is the development and demonstration of several key enabling technologies for low-temperature district heating (DH). The ambition of the DH sector to reduce temperature levels and to increase its flexibility is driven by international climate goals towards decarbonization, since those measures are crucial for replacing fossil-based heat sources by renewables and recovered waste heat.

One of the technologies developed and tested in the TEMPO project is a smart control system for the real-time operational optimization of DH systems. This system builds further upon the STORM project, in which a heat load control system for DH networks was developed using building demand response. In the TEMPO project, the scope of this smart control system was broadened towards operational optimization of network temperature levels, both in the return and supply pipes. Since the return temperature is dependent on the customers, the controller optimizes the return temperature through control of the customers' heat load. In contrast to STORM, where the thermal power profile was optimized, in TEMPO the return temperature is minimized. The network supply temperature, however, is directly controllable on the production side. The capabilities of supply temperature control are twofold. On the one hand, lowering the network supply temperature as close as possible to the limits determined by customer thermal demands. On the other hand, activating the intrinsic thermal capacity of the piping to temporarily store heat and thereby shift the heat load in time. This provides additional energy flexibility potential on top of building demand response.

In this study, the smart control system has been tested in a part of the DH network of Brescia (Italy). A cloud-based platform is used to collect real-time data from various sources and to communicate control signals calculated by the smart control algorithms. Results of the tests will be presented and evaluated in the final paper. Preliminary analysis indicates that daily-average return temperature reductions of around 1 °C on average have been achieved. Using supply temperature control, the daily peak energy generation could be reduced by 317 kWh (38%) on average, by shifting the heat load.

Keywords: Low-temperature district heating, decarbonization, smart control system, building demand response, return temperature, supply temperature, heat load shifting, energy flexibility

Currently a postdoc at DTU Compute, he holds a Ph.D. in mathematical modeling from University of Southern Denmark. Over the past 6 years he has been specializing in object-oriented modeling of fluid heating systems and electricity networks and teaching Modelica/FMI to Energy Technology students.

Evaluation of district heating operation using Flexibility Function and Functional Mockup Interface.

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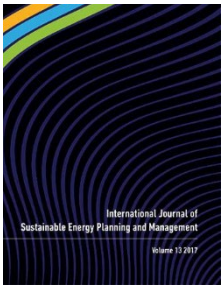
Recent development in energy flexibility characterization methods increases the quality of decision support and enables smarter energy system actuation. While the quality has been shown for electric systems, it has never been tried for fluid heating. Additionally, the demonstration of flexibility savings under real-time control of district heating would require adopting existing virtual prototyping tools, including the Functional Mockup Interface. This paper generalizes the existing flexibility evaluation approach to buildings connected to district heating and demonstrates how a cosimulation interface can be used to produce and analyze model-based energy predictions.

The used Modelica model represents a subset of the Danish district heating network considered in IBPSA project 1 Case3 (https://ibpsa.github.io/project1/cases/2020/08/10/case3_SDU.html) with network and consumers' parameters evaluated based on consumption time-series. The case is supported by a LiveLab project where main stakeholders in the Vejle North region utilize sector coupling (heat, electricity and gas) to create sustainable energy community of industrial,

residential and municipal consumers. In the residential heating part considered in the paper, the heat storage in pipes and buffer tank is a source of energy flexibility that can be utilized by the external control. For this reason, the district heating price is considered as an input and the modified heat demand as an output of the dynamic model that includes thermal storage capacities of pipes, buffer tanks and buildings.

Taken as a reference, the 12-consumer model is used in the form of a functional mockup unit to estimate the impact of consumer and network parameter variation and identify a potential difference between district heating subnetworks. The flexibility function is estimated from the model-generated data and the sensitivity analysis is performed to study the impact of network parameters on the flexibility indicators. The study shows the potential for decision support applications in district heating energy management and contributes to digitalization of district heating operations.

Keywords: Energy Flexibility, Smart District Heating, Thermal Storage, Digitalization of Energy Systems, Energy Live Lab, Grey-Box Modeling, Functional Mockup Interface, Co-simulation



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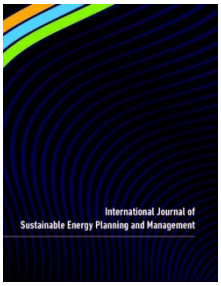

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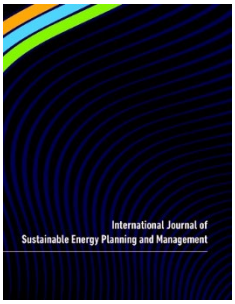

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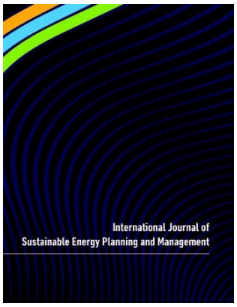

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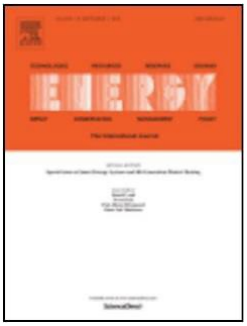

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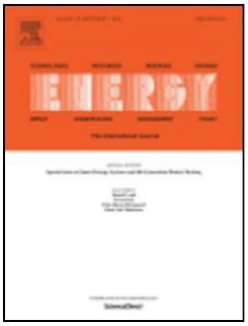

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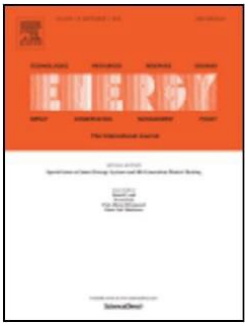

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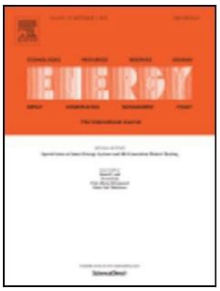

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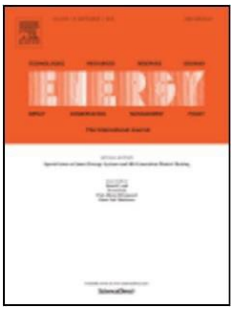

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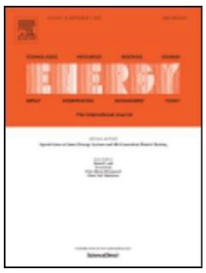

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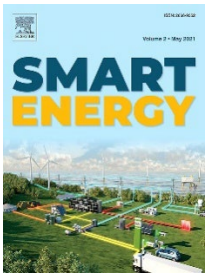

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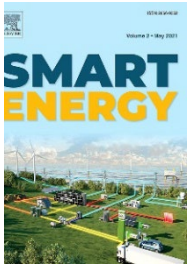

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