Book of Abstracts: 7th International Conference on Smart Energy Systems

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7TH INTERNATIONAL CONFERENCE ON SMART ENERGY SYSTEMS

Copenhagen, 21-22 September 2021

BOOK OF ABSTRACTS

AALBORG UNIVERSITY DENMARK

energy CLUSTER DENMARK

reINVEST

Innovation Fund Denmark

sEEnergies

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

7th International Conference on Smart Energy Systems
21-22 September 2021

Book of Abstracts

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Rendsburggade 14
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Preface

It is a great pleasure to welcome you to the **7th International Conference on Smart Energy Systems** on 21-22 September 2021. The conference is organised by Aalborg University and Energy Cluster Denmark. We thank the sponsors for their contribution to this year's conference: Grundfos, HOFOR, Kamstrup, LOGSTOR, Danfoss, INNARGI and Vestas.

COVID 19 has affected lives, societies, energy systems, working conditions and research throughout the world since March 2020 and it has also affected this year's SES Conference. In 2020, we adopted a robust hybrid approach by deciding to enable both physical and virtual attendance. In the end, new COVID 19 regulations forced us to hold the conference exclusively as an online event last year, and we thank those of you attending for your continuous support in uncertain times. In 2021, we draw on our experience from last year and again plan a hybrid conference; and with high vaccination rates among many of the nationalities typically attending the conference, we expect to have a fruitful physical event this year – while still allowing attendees not able to attend physically to gain from the conference.

While the pandemic surged the world, and seemingly stopped the world, we have only seen minor setbacks in the deployment of renewable energy and energy efficiency technologies. On the other hand, the energy related emissions did not decrease as much as anticipated. Even though the pandemic hit, renewables accelerated the expansion and it is evident that integration measures are needed. The fast development of fluctuating renewable energy sources will increasingly challenge the design of the energy systems globally.

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 7th 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 more than 20 countries around the world – to a programme with 120 presentations, panel debate, side event and technical tours in Copenhagen. 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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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 2021

15 Apr	**Deadline for submission of abstracts** (Additional upgrade to paper is optional)
11 May	**Reply on acceptance of abstracts**
12 May - 11 Jun	**Early registration**
12 Jun - 31 Aug	**Normal registration**
21 - 22 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): **300 EUR** (attendance in Copenhagen) / **200 EUR** (virtual attendance)
- Normal fee: **400 EUR** (attendance in Copenhagen) / **300 EUR** (virtual attendance)
- Additional fee for conference dinner (Copenhagen): **100 EUR**

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Aim and Organisers

After being forced by circumstances into holding the 6th Conference strictly virtually in 2020, we look forward to yet again welcoming our conference participants in a hybrid setting with the possibility to attend either online or in person – this time in Copenhagen.

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 7th 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 with support from the RE-INVEST and the sEEnergies projects.

RE-INVEST is an international research project, which develops robust and cost-effective renewable energy investment strategies for Denmark and Europe. RE-Invest has received funding from Innovation Fund Denmark, no. 6154-00022B.

sEEnergies is a European research project focusing on Smart Energy Systems and supply chain effects on energy efficiency in all sectors and infrastructure. sEEnergies is funded by the European Union's Horizon 2020 Research and Innovation Programme, GA no. 846463.

Conference Chairs

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

Submission Procedure

Abstracts can be submitted via **www.smartenergysystems.eu** from **5 February to 15 April 2021.**

Both scientific and industrial contributions to the conference are most welcome. Submitted abstracts will be reviewed by a scientific and an industrial committee. Authors of approved abstracts 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 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

Ass. Prof. Benedetto Nastasi, Sapienza University of Rome, IT
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LIVE SESSIONS

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Tuesday 21 September 2021 at 09:00-11:00 — LIVE SESSION

09:00-11:00 1st plenary session chaired by Professor Poul Alberg Østergaard

09:00-09:10 **Professor Henrik Lund:** Opening speech

09:10-09:30 **Keynote (online): Claudia Kemfert, Professor and Head of Department at DIW, Germany:** Corona crisis: Chance for decentralized energy system transformation with full supply from renewable energies

09:30-09:40 Questions and debate

09:40-10:10 **Keynote: Anders Nordstrøm, Vice President of Hydrogen at Ørsted, Denmark:** PTX potential for 2050 net zero

10:10-10:40 **Keynote: Poul Skjærbæk, Chief Innovation Officer at Siemens Gamesa, Denmark:** Unlocking the Green Hydrogen revolution at the sea

10:40-11:00 Questions and debate

Wednesday 22 September 2021 at 13:45-16:00 — LIVE SESSION

13:45-16:00 2nd plenary session chaired by Professor Brian Vad Mathiesen

13:45-14:15 **Keynote: Liliana Proskuryakova, Deputy Head and leading researcher at HSE, Russia:** The future of renewable energy and renewable energy systems in Russia

14:15-14:30 Questions and debate

14:30-15:00 **Keynote: Rufus Gifford, former U.S. ambassador to Denmark and nominee for Chief of Protocol at the U.S. State Department:** The new climate policies under the Biden Administration and the global challenges for the Paris Agreement

15:00-15:40 Questions and debate

15:40-15:50 Best Presentation Award Ceremony by Professor Poul Alberg Østergaard

15:50-16:00 Closing by Professor Henrik Lund and CEO Glenda Napier

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SESSIONS OPEN 17-24 SEPTEMBER 2021

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AALBORG UNIVERSITY

Smart energy system analyses, tools and methodologies

Lorenzo Cassetti: Realization and energy assessment algorithm of a Horizontal Packed Bed Regenerator for Thermal Energy Storage

Mostafa Fallahnejad: District heating distribution grid costs: comparison of two approaches

Tao Feng: Companies' acceptance of innovative energy facility: Results of a simultaneous equation approach

Kirstin Ganz: How can energy system modeling electricity prices be adjusted to reflect real price spreads for flexible assets in the future?

Regina Hemm: Optimization of the bidding strategy of a virtual power plant by participating in short-term, balancing- and redispatch markets

Jin Hur: A practical metric to evaluate the ramp events of wind generating resources to enhance the security of Smart Energy Systems

Thanh Huynh: Local Energy Markets for Thermal-Electric Energy Systems considering energy carrier dependency and energy storages

Jiao Jiao: Text Mining based Identification of Emerging Technologies and Business Models for Smart Energy Systems

Nicola Kleppmann: ML4Heat - Tools for the optimized operation of existing district heating networks based on machine learning methods

Kevin Knosala: Generic Input Generation for Residential District Energy System Models from Open Data for Germany

Lukas Kranzl: The economic potential of district heating under climate neutrality: the case of Austria

Jacopo de Maigret: A multi-objective optimization approach in defining the decarbonisation strategy of a refinery

Marko Mimica: A stochastic model for smart energy systems analysis

Adrian Ostermann: Forecasting charging station occupancy using supervised learning algorithms

Martin Lindgaard Pedersen: Digital tools for refurbishment planning based on facts and choice of pipe system based on Total Cost of Ownership and CO_2 emission

Tim Pedersen: Modeling all alternative solutions for highly renewable energy systems

Matteo Giacomo Prina: Bottom-up method to derive Cost curves for heat savings in buildings for all European countries

Callum Rae: What can past examples teach us about the rollout and scale-up of smart energy systems?

Morten Karstoft Rasmussen: Connecting the DH value chain with smart meter data

Dmitry Romanov: District heating systems modelling: A gamification approach

Costanza Saletti: A hierarchical control algorithm with yearly and daily horizons for optimally managing district energy systems

Salman Siddiqui: District heating and the GB electricity system in a zero-emission scenario

Goran Stunjek: Analysis of hydropower impact in water energy nexus for smart energy systems

Anna Vannahme: General Optimization Guideline for District Heating Networks and its exemplary Application

Volodymyr Voloshchuk: Exergy-based performance degradation diagnosis for use in digital twins of thermal systems

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Smart energy infrastructure and storage options

David Barns: Enabling geoexchange in cities: success factors from UK examples

Morten Vang Bobach: Multi-purpose Pit Thermal Energy Storage in Combination with Heat Pumps

Charles Hansen: Reducing carbon emissions through low temperature district heating zones

Pietro Lubello: Assessment of hydrogen based long-term electrical energy storage in residential energy systems

Andrew Lyden: Seasonal thermal energy storage in smart energy systems to provide flexibility services

Erika Dal Monte: Thermal Storage Integration in a Smart Thermal Grid

Michael Reisenbichler: Methodology development for accelerated generation of thermal energy storage models for transient system simulations: Towards more efficient modeling and simulation of large-scale hot-water underground pit and tank TES

Thomas Riegler: Novel cover design with usable surface for large-scale pit thermal energy storages

Jesper Tange: Improving efficiency and scaling up Pit Thermal Energy Storages (PTES) with unique lid design

Integrated energy systems and smart grids

Mads R. Almassalkhi: Characterizing the reactive power capability of wind farm collector networks

Marie-Alix Dupré la Tour: Flexibility enhancement using heat networks within large scale sector coupling studies

Søren Lyng Ebbehøj: Potential roles for power-to-x and CCUS technologies in Denmark's green transition

Philip Fosbøl: Potential for CCS and CCUS electrification towards reducing impact of climate change

Oddgeir Gudmundsson: The role of hydrogen in the future heat supply system

Anders Bavnhøj Hansen: System scenarios towards climate neutrality by use of smart Energy systems solutions

David Huckebrink: Coupling and comparison of hydrogen technologies with heat-pumps to decarbonise the residential heating sector

Andrei David Korberg: Supply chain effects of the extreme hydrogen society

Mathias Müller: Future grid load with bidirectional electric vehicles

Thomas Natiesta: Testbed to evaluate digital solutions in integrated district heating and electrical grids: First results

Henrik Schwaeppe: Analysing systemic advantages of district heating in an integrated transmission and generation expansion planning model

Lu Shen: Multi-energy cluster partition with CHPs for distributed optimization and control of the integrated energy system

Hammam Soliman: Power-to-X / Electricity-to-Hydrogen – CAPEX & OPEX Vs. Integrated Production

Special Session: IEA DHC Annex TS3

Ralf-Roman Schmidt: Integrated District Heating and Cooling Systems: Overview of the results of the international cooperation project IEA DHC Annex TS3

Peter Sorknæs: Energy system synergies of hybrid energy network technologies

Edmund Widl: Categorization of tools and methods for modeling and simulating hybrid energy systems

Anton Ianakiev: Hybrid Energy Networks - Demo Case studies

Dennis Cronbach: On business models and the regulatory framework of hybrid grids

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Planning and organisational challenges for smart energy systems and district heating

Sara Ben Amer: How successful is municipal energy planning in Denmark - quantifying the impact

Dagnija Blumberga: Smart Heat Tariffs in transition to free market

Claudia Mădălina Dumitru: Optimizing the development process of a hybrid energy supply system based on renewable sources using the LEAN methodology

Pei Huang: 5th generation district heating and cooling implementation potential in urban areas with existing district heating systems

Tore Friis Gad Kjeld: District Heating in Copenhagen – challenges and perspectives

Britta Kleinertz: Heat Transformation Munich – Analysis and strategy definition for a systemic cost optimal heat supply transformation

Ari Laitala: Understanding the profitability of the energy (efficiency) investments – things to consider before putting billions into game

Hannah Mareike Marczinkowski: Modelling renewable energy islands and their role in energy transitions

David Maya-Drysdale: Achieving carbon neutrality in cities: Lessons from a leader

Matteo Pozzi and **Alessandro Capretti**: Planning large district heating network developments based on Waste Heat Recovery

Alexandra Purkus: Guarantees of Origin for green district heating: An analysis of legal framework conditions and system design options

Daniel Møller Sneum: Discounting assumptions in district energy

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

Vittoria Battaglia: The role of local energy planning in the achievements of regional and national sustainability targets: an Italian case study

Gerald Birngruber: Digital Energy Twins - Optimised Operation and Design of Industrial Energy Systems

Marcus Hummel: How cost efficient is energy efficiency in buildings? A comparison of building shell efficiency & heating system change in the European building stock

Philipp Mascherbauer: Investigating the demand side flexibility of the building stock

Nikola Matak: Selection of mitigation actions in Smart SECAPs through comparison of individual and joint implementation

Hironao Matsubara: 100% Renewable Energy Scenario in Tokyo metropolitan area with green recovery by 2050

Andreas Müller: How to decarbonize Munich's district heating production in long -term? Forecasting the space heating demand of Munich

Tobias Reum: Experimental Investigation of a novel Hybrid Heat Pump

Daniel Trier: Large-scale heat pumps for district heating – Lessons learned from real applications

Pierre JC Vogler-Finck: Data-driven operation of building heating to support the energy transition at community level – Learnings from field applications

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

Felix Agner: Improving robustness to peak load conditions in district heating networks through scalable control coordination subject to network constraints

Jakob Binder: Interconnection and smart control of district heating networks for increased flexibility

Luca Casamassima: A proposed Pathway to future-proof current building stock for upcoming 4th generation district heating in the scope of Positive Energy Districts

Marco Cozzini: Performance measurement and detailed modelling of an existing neutral -temperature district heating network based on decentralized heat pumps

Christian Engel: Green deal impact of DHC networks: how best preforming piping systems make DHC even more attractive

Jonas Gottschald: Data-based multi-criteria operational optimization of district heating supply while reducing balancing energy

Joseph Maria Jebamalai: Design of Two Pipe District Heating and Cooling Networks using Ring and Meshed Network Configuration – A Case Study

Hanne Kauko: Investment analysis of a local energy system with seasonal thermal energy storage

Henrik Lund: Transition to 4th Generation District Heating and Motivation Tariffs

Kristina Lygnerud: Implementation of low temperature district heating

Yannis Merlet: Formulation and assessment of multi-objective sizing: application to low temperature District-Heating networks

Ali Moallemi: COOL DH: A Pioneering Project to Implement Low Temperature District Heating (LTDH) Systems As an Integrated Part of Smart Energy Systems

Kevin Naik: A real-life data driven model for district heating

Ieva Pakere: Pathways toward carbon neutral 4th generation district heating system in Latvia

Rémi Patureau: Comparison of two district heating and cooling designs based on dynamic simulation

Stefan Puschnigg: An analysis of cascaded low-temperature sub-networks in existing district heating networks

Dietrich Schmidt: Low temperature district heating as a proven and market ready technology – Case studies of IEA DHC ANNEX TS2

Artem Sotnikov: Hydrothermal challenges in low-temperature networks with distributed heat pumps

Jan Eric Thorsen: Insights on domestic hot water consumption for multi flat buildings

Marc-André Triebel: Techno-Economic and Ecological Evaluation of Different District Heating Network Generations for two German Districts

Anna Volkova: Competitiveness of individual heat pumps in the Baltic states

Sven Werner: Network configurations for low-temperature district heating

Meng Yuan: District heating in 100% renewable energy systems: Combining industrial excess heat and heat pumps

Dorte Skaarup Østergaard: Combined district heating and cooling – which solutions are available and are they applicable in a Danish context?

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Electrification of transport, heating and industry

Annika Boldrini: On the role of district heating systems to provide balancing services in the EU

Georg Brandstätter: Efficient area of operation planning for free-floating electric car sharing systems

Leif Gustavsson: A lifecycle comparison of primary energy use and climate impact of biofuel and electric cars

Sajjad Haider: A novel, decentralized spatial pricing model for peer-to-peer electricity distribution to consumers and electric vehicles

Kertu Lepiksaar: Centralised power-to-heat units as flexible consumers in the power grid

Oliver Ruhnau: How flexible electricity demand stabilizes wind and solar market values: The case of hydrogen electrolyzers

Kasper T. Therkildsen: Large scale deployment of modular pressurised alkaline electrolysers

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

Andra Blumberga: Spatial analyses of smart energy system implementation through system dynamics and GIS modelling

Alice Dénarié: An open spatial optimisation model to asses economically sustainable national district heating potential

Hermann Edtmayer: Urban Building Thermal Energy Analysis at City District Scale

Bernd Möller: An empirical high-resolution geospatial model of future population distribution for assessing heat demands

Ulrich Reiter: Decarbonizing the Swiss energy demand from buildings

Abdulraheem Salaymeh: Assessment of the influence of demographics, refurbishment and the climate on the heat demand in district heating planning

Luis Sánchez-García: A Closer Look at the Effective Width for District Heating Systems

Renewable energy sources and waste heat sources for district heating

Dario Dall'Ara: Solar energy in low temperature district heating: monitoring and simulation of an innovative district in Milan

Patrick Geiger: RES-DHC - Transformation of existing urban district heating and cooling systems from fossil to renewable energy sources

Eduard Latõšov: CO2 emission intensity of the Estonian district heating sector

Aleksandr Ledvanov: Free cooling and district heating supply usage for Tallinn district cooling production

Mihai-Rareș Sandu: Analysis and optimisation of a renewable energy hybrid system operation

Peter Verboven: R-ACEs: fRamework for Actual Cooperation on Energy on Sites and Parks

Vladimir Vidović: Solving barriers for effective utilization of Seawater Heat Pumps for heating and cooling in the Adriatic region

Jelena Ziemele: Validity assessment of the waste heat integration into a district heating system: Case of the city of Riga

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ONLINE PROGRAMME

THURSDAY 23 SEPTEMBER 2021

Online side event: Geothermal District Heating and Cooling

Thursday 23 September 2021

09:30 – 11:00 (9:30 - 11 am)

Geothermal District Heating and Cooling is an online side event organised by IRENA and EGEC in the framework of the International Conference on Smart Energy Systems and under the Umbrella of the of the Global Geothermal Alliance.

IRENA and EGEC co-organise this event to promote the deployment of geothermal energy for heating and cooling. The event will promote the development of district energy networks as a means to increase the share of renewables, including geothermal energy in the heating of buildings and the supply of domestic hot water. It will facilitate sharing of experiences and best practices as well as highlighting supportive tools, methodologies and options.

The event will be held virtually over the IRENA zoom platform for a duration of 1h 30 minutes.

Read more about the side event and register via IRENA.

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PROGRAMME COPENHAGEN
MONDAY 20 SEPTEMBER 2021

Technical Tour: Middelgrunden Wind farm

Monday 20 September 2021
14:00 – 17:30 (2 pm – 5.30 pm)

The Middelgrunden Offshore Wind Farm is one of the first offshore wind farms in the world. It has a total capacity of 40 MW and consists of 20 Bonus turbines each with a power of 2 MW. Middelgrunden Offshore Wind Farm provides 3 per cent of the electricity consumption in Copenhagen.

The tour includes boat trip to Middelgrunden Offshore Wind Farm with participation from Middelgrunden Wind Turbine Cooperative (duration: 2-3 hours depending on weather); explanation about the project, ownership structure etc., coffee/tea, and, if permitted by the weather, entrance to the turbine foundation.

Departure from Amaliehaven (Amalie Garden), Larsens Plads, 1253 Copenhagen K

More information and registration at conference website.

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PROGRAMME COPENHAGEN

TUESDAY 21 SEPTEMBER 2021

energy CLUSTER DENMARK

AALBORG UNIVERSITY

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

09:00-11:00 **1st plenary session chaired by Professor Poul Alberg Østergaard** — **ROOM: SQUARE 1**

09:00-09:10 **Professor Henrik Lund:** Opening speech

09:10-09:30 **Keynote (online): Claudia Kemfert, Professor and Head of Department at DIW, Germany:** Corona crisis: Chance for decentralized energy system transformation with full supply from RE

09:30-09:40 Questions and debate

09:40-10:10 **Keynote: Anders Nordstrøm, Vice President of Hydrogen at Ørsted, Denmark:** PTX potential for 2050 net zero

10:10-10:40 **Keynote: Poul Skjærbæk, Chief Innovation Officer at Siemens Gamesa, Denmark:** Unlocking the Green Hydrogen revolution at the sea

10:40-11:00 Questions and debate

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

Parallel sessions 1-4

11:15-12:30 — ROOM: SQUARE 1

Session 1: Smart energy system analyses, tools and methodologies

Chair: Ulrich Reiter

Session keynote Martin Lindgaard Pedersen: Digital tools for refurbishment planning based on facts and choice of pipe system based on Total Cost of Ownership and CO2 emission

Mostafa Fallahnejad: District heating distribution grid costs: comparison of two approaches

Kirstin Ganz: How can energy system modeling electricity prices be adjusted to reflect real price spreads for flexible assets in the future?

Anna Vannahme: General Optimization Guideline for District Heating Networks and its exemplary Application

11:15-12:30 — ROOM: SQUARE 2

Session 2: Integrated energy systems and smart grids

Chair: Jesper Tange

Session keynote Oddgeir Gudmundsson: The role of hydrogen in the future heat supply system

Søren Lyng Ebbehøj: Potential roles for power-to-x and CCUS technologies in Denmark's green transition

Hammam Soliman: Power-to-X / Electricity-to-Hydrogen – CAPEX & OPEX Vs. Integrated Production

Thomas Natiesta: Testbed to evaluate digital solutions in integrated district heating and electrical grids: First results

11:15-12:30 — ROOM: SQUARE 3

Session 3: Planning and organisational challenges for smart energy systems and district heating

Chair: David Maya-Drysdale

Session keynote Matteo Pozzi and **Alessandro Capretti**: Planning large district heating network developments based on Waste Heat Recovery

Claudia Mădălina Dumitru: Optimizing the development process of a hybrid energy supply system based on renewable sources using the LEAN methodology

Ari Laitala: Understanding the profitability of the energy (efficiency) investments – things to consider before putting billions into game

Daniel Møller Sneum: Discounting assumptions in district energy

11:15-12:30 — ROOM: BACKSTAGE

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

Chair: Hanne Kauko

Session keynote Anna Volkova: Competitiveness of individual heat pumps in the Baltic states

Felix Agner: Improving robustness to peak load conditions in district heating networks through scalable control coordination subject to network constraints

Marco Cozzini: Performance measurement and detailed modelling of an existing neutral-temperature district heating network based on decentralized heat pumps

Stefan Puschnigg: An analysis of cascaded low-temperature sub-networks in existing district heating networks

7th International Conference on

Smart Energy Systems

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

21-22 September 2021, Copenhagen

#SESAAU2021

PROGRAMME COPENHAGEN
TUESDAY 21 SEPTEMBER 2021

12:30-14:00 Lunch and networking

Parallel sessions 5-8

14:00-15:30 ROOM: SQUARE 1

Session 5: Smart energy system analyses, tools and methodologies

Chair: Anders N. Andersen

Session keynote Matteo Giacomo Prina: Bottom-up method to derive Cost curves for heat savings in buildings for all European countries

Lorenzo Cassetti: Realization and energy assessment algorithm of a Horizontal Packed Bed Regenerator for Thermal Energy Storage

Adrian Ostermann: Forecasting charging station occupancy using supervised learning algorithms

Thanh Huynh: Local Energy Markets for Thermal-Electric Energy Systems considering energy carrier dependency and energy storages

Goran Stunjek: Analysis of hydropower impact in water energy nexus for smart energy systems

14:00-15:30 ROOM: SQUARE 2

Session 6: Integrated energy systems and smart grids

Chair: Hans Jørgen Brodersen

Session keynote Philip Fosbøl: Potential for CCS and CCUS electrification towards reducing impact of climate change

Anders Bavnhøj Hansen: System scenarios towards climate neutrality by use of smart Energy systems solutions

Mads R. Almassalkhi: Characterizing the reactive power capability of wind farm collector networks

Marie-Alix Dupré la Tour: Flexibility enhancement using heat networks within large scale sector coupling studies

Henrik Schwaeppe: Analysing systemic advantages of district heating in an integrated transmission and generation expansion planning model

14:00-15:30 ROOM: BACKSTAGE

Session 7: Planning and organisational challenges for smart energy systems and district heating

Chair: Peter Jorsal

Session keynote Tore Friis Gad Kjeld: District Heating in Copenhagen – challenges and perspectives

Sara Ben Amer: How successful is municipal energy planning in Denmark - quantifying the impact

David Maya-Drysdale: Achieving carbon neutrality in cities: Lessons from a leader

Britta Kleinertz: Heat Transformation Munich – Analysis and strategy definition for a systemic cost optimal heat supply transformation

Hannah Mareike Marczinkowski: Modelling renewable energy islands and their role in energy transitions

14:00-15:30 ROOM: SQUARE 3

Session 8: 4th Generation District Heating concepts, future district heating production and systems

Chair: Steffen Nielsen

Session keynote Kristina Lygnerud: Implementation of low temperature district heating

Henrik Lund: Transition to 4th Generation District Heating and Motivation Tariffs

Luca Casamassima: A proposed Pathway to future-proof current building stock for upcoming 4th generation district heating in the scope of Positive Energy Districts

Jakob Binder: Interconnection and smart control of district heating networks for increased flexibility

Meng Yuan: District heating in 100% renewable energy systems: Combining industrial excess heat and heat pumps

15:30-16:15 Coffee break

7th International Conference on

Smart Energy Systems

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

21-22 September 2021, Copenhagen

#SESAAU2021

PROGRAMME COPENHAGEN
TUESDAY 21 SEPTEMBER 2021

energy CLUSTER DENMARK

AALBORG UNIVERSITY

Parallel sessions 9-12

16:15-17:30 ROOM: SQUARE 1	16:15-17:30 ROOM: BACKSTAGE	16:15-17:30 ROOM: SQUARE 2	16:15-17:30 ROOM: SQUARE 3
Session 9: 4th Generation District Heating concepts, future district heating production and systems	**Session 10: Energy savings in the electricity sector, buildings, transport and industry**	**Session 11: Renewable energy sources and waste heat sources for district heating**	**Session 12: Geographical Information Systems (GIS) for energy systems, heat planning and district heating**
Chair: Ralf-Roman Schmidt	**Chair: Anne B. Holm**	**Chair: Goran Krajačić**	**Chair: Urban Persson**
Session keynote Christian Engel: Green deal impact of DHC networks: how best preforming piping systems make DHC even more attractive	**Session keynote Tobias Reum**: Experimental Investigation of a novel Hybrid Heat Pump	**Session keynote Aleksandr Ledvanov**: Free cooling and district heating supply usage for Tallinn district cooling production	**Session keynote Bernd Möller**: An empirical high -resolution geospatial model of future population distribution for assessing heat demands
Hanne Kauko: Investment analysis of a local energy system with seasonal thermal energy storage	**Philipp Mascherbauer**: Investigating the demand side flexibility of the building stock	**Dario Dall'Ara:** Solar energy in low temperature district heating: monitoring and simulation of an innovative district in Milan	**Hermann Edtmayer**: Urban Building Thermal Energy Analysis at City District Scale
Ali Moallemi: COOL DH: A Pioneering Project to Implement Low Temperature District Heating (LTDH) Systems As an Integrated Part of Smart Energy Systems	**Nikola Matak**: Selection of mitigation actions in Smart SECAPs through comparison of individual and joint implementation	**Mihai-Rareș Sandu:** Analysis and optimisation of a renewable energy hybrid system operation	**Ulrich Reiter**: Decarbonizing the Swiss energy demand from buildings
Dorte Skaarup Østergaard: Combined district heating and cooling – which solutions are available and are they applicable in a Danish context?	**Gerald Birngruber**: Digital Energy Twins - Optimised Operation and Design of Industrial Energy Systems	**Vladimir Vidović:** Solving barriers for effective utilization of Seawater Heat Pumps for heating and cooling in the Adriatic region	**Luis Sánchez-García**: A Closer Look at the Effective Width for District Heating Systems

17:30-19:30 Break

19:30 Conference dinner, Restaurant GRØFTEN in Tivoli

4DH reINVEST Innovation Fund Denmark sEEnergies

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

LOGSTOR INNARGI HOFOR kamstrup ENGINEERING TOMORROW Danfoss Vestas GRUNDFOS

7th International Conference on

Smart Energy Systems

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

21-22 September 2021, Copenhagen

#SESAAU2021

PROGRAMME COPENHAGEN
WEDNESDAY 22 SEPTEMBER 2021

energy CLUSTER DENMARK

AALBORG UNIVERSITY

Parallel sessions 13-15

09:00-10:30 — ROOM: SQUARE 1

Session 13: Energy savings in the electricity sector, buildings, transport and industry

Chair: Bernd Möller

Session keynote Marcus Hummel: How cost efficient is energy efficiency in buildings? A comparison of building shell efficiency & heating system change in the European building stock

Andreas Müller: How to decarbonize Munich's district heating production in long-term? Forecasting the space heating demand of Munich

Pierre JC Vogler-Finck: Data-driven operation of building heating to support the energy transition at community level – Learnings from field applications

Daniel Trier: Large-scale heat pumps for district heating – Lessons learned from real applications

Vittoria Battaglia: The role of local energy planning in the achievements of regional and national sustainability targets: an Italian case study

09:00-10:30 — ROOM: SQUARE 2

Session 14: Smart energy infrastructure and storage options

Chair: Jan Eric Thorsen

Session keynote Charles Hansen: Reducing carbon emissions through low temperature district heating zones

David Barns: Enabling geoexchange in cities: success factors from UK examples

Morten Vang Bobach: Multi-purpose Pit Thermal Energy Storage in Combination with Heat Pumps

Pietro Lubello: Assessment of hydrogen based long-term electrical energy storage in residential energy systems

Jesper Tange: Improving efficiency and scaling up Pit Thermal Energy Storages (PTES) with unique lid design

09:00-10:30 — ROOM: SQUARE 3

Session 15: Special Session IEA DHC Annex TS3

Chair: Dorte Østergaard

Session keynote Ralf-Roman Schmidt: Integrated District Heating and Cooling Systems: Overview of the results of the international cooperation project IEA DHC Annex TS3

Peter Sorknæs: Energy system synergies of hybrid energy network technologies

Edmund Widl: Categorization of tools and methods for modeling and simulating hybrid energy systems

10:30-11:00 **Coffee break**

4DH — reINVEST — Innovation Fund Denmark — sEEnergies

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

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7th International Conference on

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21-22 September 2021, Copenhagen

#SESAAU2021

PROGRAMME COPENHAGEN

WEDNESDAY 22 SEPTEMBER 2021

energy CLUSTER DENMARK

AALBORG UNIVERSITY

Parallel sessions 16-18

11:00-12:30 **ROOM: SQUARE 1**

Session 16: Smart energy system analyses, tools and methodologies

Chair: Steen Schelle Jensen

Session keynote Morten Karstoft Rasmussen: Connecting the DH value chain with smart meter data

Marko Mimica: A stochastic model for smart energy systems analysis

Tim Pedersen: Modeling all alternative solutions for highly renewable energy systems

Dmitry Romanov: District heating systems modelling: A gamification approach

Costanza Saletti: A hierarchical control algorithm with yearly and daily horizons for optimally managing district energy systems

11:00-12:30 **ROOM: SQUARE 2**

Session 17: 4th Generation District Heating concepts, future district heating production and systems

Chair: Peter Sorknæs

Session keynote Jan Eric Thorsen: Insights on domestic hot water consumption for multi flat buildings

Dietrich Schmidt: Low temperature district heating as a proven and market ready technology – Case studies of IEA DHC ANNEX TS2

Artem Sotnikov: Hydrothermal challenges in low-temperature networks with distributed heat pumps

Kevin Naik: A real-life data driven model for district heating

Nicola Kleppmann: ML4Heat - Tools for the optimized operation of existing district heating networks based on machine learning methods

11:00-12:30 **ROOM: SQUARE 3**

Session 18: Electrification of transport, heating and industry

Chair: Anders Bavnhøj Hansen

Session keynote Leif Gustavsson: A lifecycle comparison of primary energy use and climate impact of biofuel and electric cars

Kertu Lepiksaar: Centralised power-to-heat units as flexible consumers in the power grid

Oliver Ruhnau: How flexible electricity demand stabilizes wind and solar market values: The case of hydrogen electrolyzers

Kasper T. Therkildsen: Large scale deployment of modular pressurised alkaline electrolysers

Andrei David Korberg: Supply chain effects of the extreme hydrogen society

12:30-13:45 **Lunch and networking**

13:45-16:00	**2nd plenary session chaired by Professor Brian Vad Mathiesen** **ROOM: SQUARE 1**
13:45-14:15	**Keynote: Liliana Proskuryakova, Deputy Head and leading researcher at HSE, Russia:** The future of renewable energy and renewable energy systems in Russia
14:15-14:30	Questions and debate
14:30-15:00	**Keynote: Rufus Gifford, former U.S. ambassador to Denmark and nominee for Chief of Protocol at the U.S. State Department:** The new climate policies under the Biden Administration and the global challenges for the Paris Agreement
15:00-15:40	Questions and debate
15:40-15:50	Best Presentation Award Ceremony by Professor Poul Alberg Østergaard
15:50-16:00	Closing by Professor Henrik Lund and CEO Glenda Napier

Technical Tour: Waste-to-energy Plant: ARC - and the CCS project

Thursday 23 September 2021
09:00 – 14:00 (9 am – 2 pm)

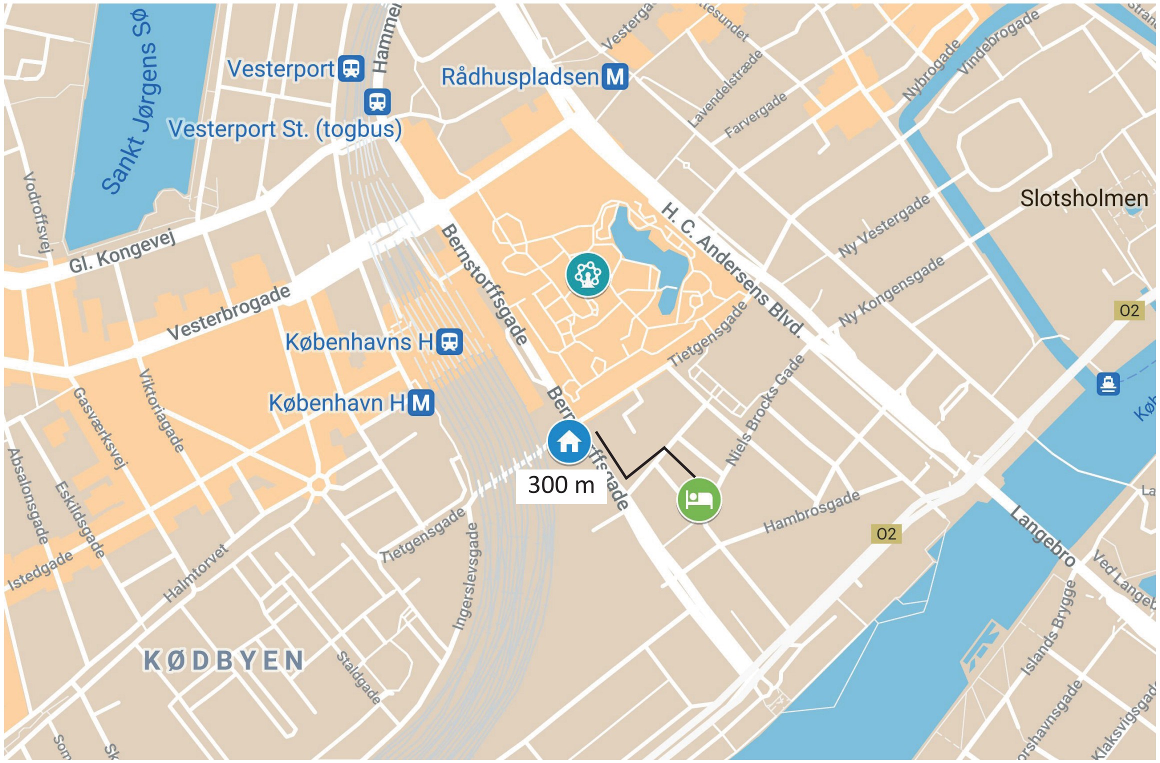
ARC (Amager Ressourcecenter) is a waste treatment company owned by five municipalities in Copenhagen. ARC runs the waste-to-energy plant Amager Bakke, 16 recycling centres, etc., and handles waste from 645,000 citizens and 68,000 companies. In 2020, ARC incinerated almost 600,000 tons of non-recyclable, residual waste and turned it into 244 GWh of electricity and 1,363 GWh of district heating. The vision of ARC is to make waste treatment and incineration net zero/carbon neutral. One step is by implementing an extra cleaning filter that captures CO2 from the flue gas. In collaboration with the Technical University of Denmark, ARC set up a demonstration project in 2021. This is the first CCS project connected to a waste-to-energy plant in Denmark. The technology behind carbon capture is extremely energy intensive. By integrating CO2 capture into the district heating system, ARC's demonstration project aims to show that CO2 capture can be achieved with neutral energy consumption. The tour includes transport from city centre to ARC waste treatment plant + transport from ARC to airport; presentation on Waste treatment in ARC, Waste-to-Energy and Carbon Capture project, guided tour incl. visit at CCS test facilities, lunch as well as an optional visit to the recreational rooftop. Departure by bus from Copenhagen city (bus boarding site to be announced). The tour ends at Copenhagen airport at 14:00.

More information and registration at the conference website.

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

Map of Copenhagen

Conference area



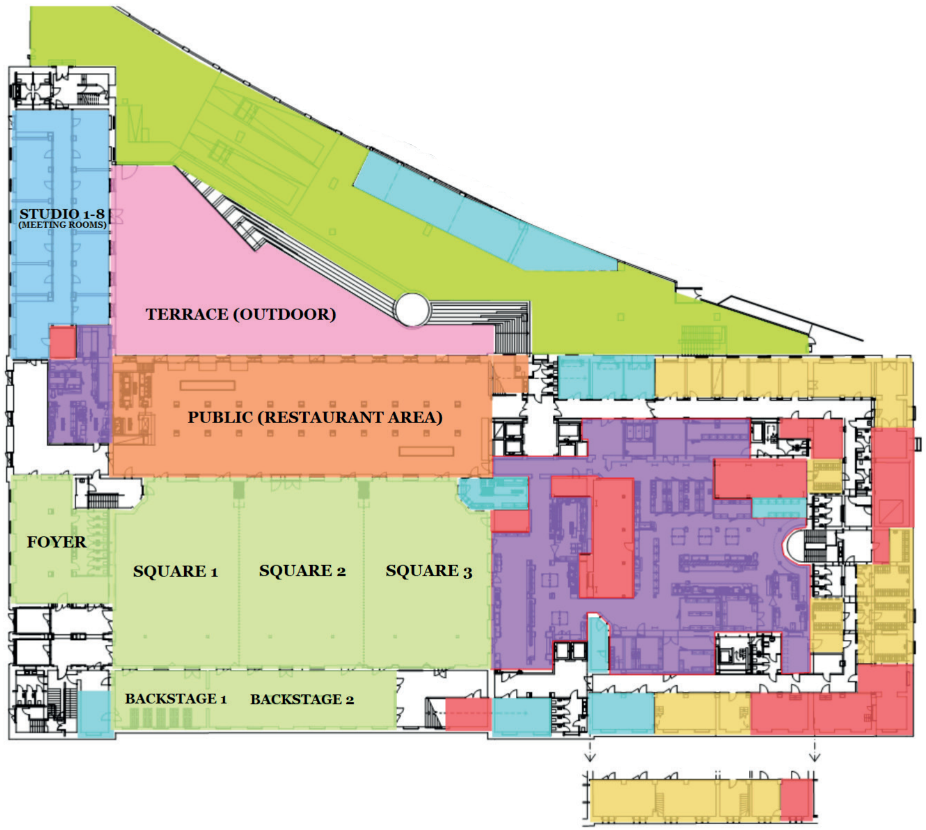
Hotel - Cabinn City

Conference dinner venue - Restaurant Grøften

Conference venue - Villa Copenhagen

Villa Copenhagen

Floor plan




Kamstrup

kamstrup

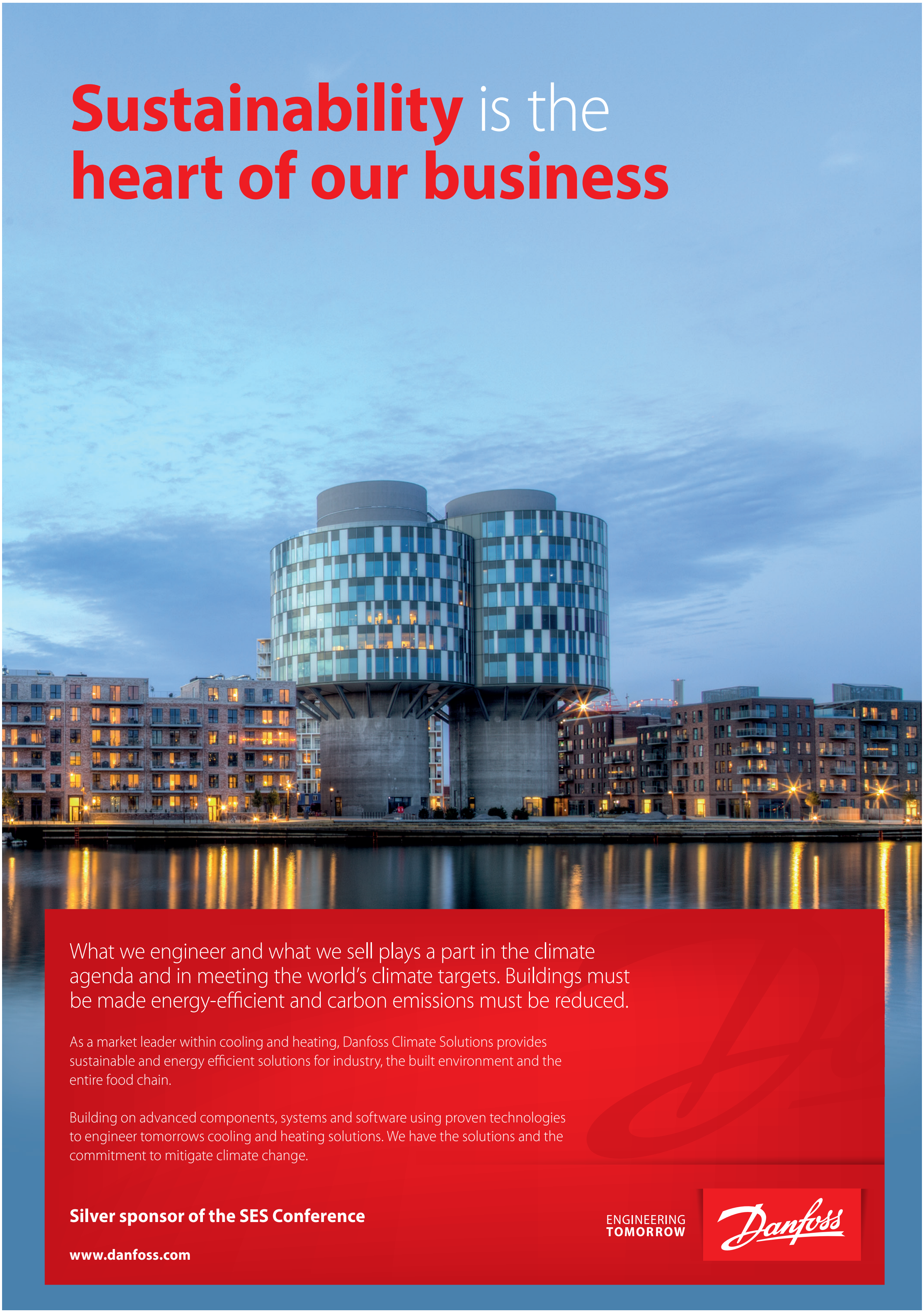
Best Presentation Award is donated by Kamstrup

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


Sustainability is the
heart of our business
What we engineer and what we sell plays a part in the climate agenda and in meeting the world's climate targets. Buildings must be made energy-efficient and carbon emissions must be reduced.
As a market leader within cooling and heating, Danfoss Climate Solutions provides sustainable and energy efficient solutions for industry, the built environment and the entire food chain.
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Previous winners of the Best Presentation Awards

Best PhD Presentation:

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:

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

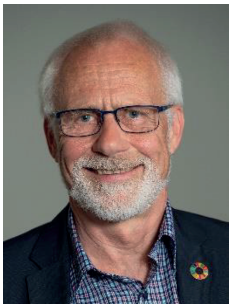
Professor Henrik Lund is Editor-in-Chief of Elsevier's international journal ENERGY and a world leading scientist. He is ranked among the top 1% researchers on the world on the Thomson Reuter's list of highly cited researchers. He holds a PhD in "Implementation of sustainable energy systems" (1990) and 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

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

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

Poul Alberg Østergaard is Professor in Energy Planning at Aalborg University. He holds a PhD in "Integrated Resource Planning" (2000) and has more than 20 years of research and teaching experience within Energy Planning. 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.

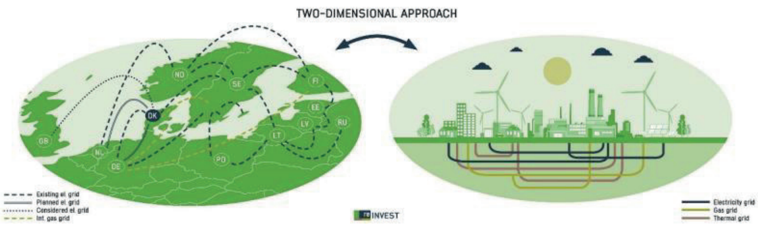
RE-INVEST aims at designing robust and cost-effective investment strategies that will facilitate an efficient transformation towards a sustainable or 100% renewable energy system in Denmark and Europe.

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

Rufus Gifford is a former U.S. Ambassador, senior aide to President Barack Obama and President Joe Biden, civic leader, public speaker, an advocate for Democratic causes and current Nominee for Chief of Protocol for the United States with the rank of Ambassador.

Most recently he was Deputy Campaign Manager for Biden for President with a focus on finance, external outreach and coalition building. Gifford was responsible for the record-shattering 1.5 billion dollars raised by the Biden Campaign in the general election. Aside from Presidential politics, he is focused on promoting civic engagement, particularly among youth and issue areas ranging from U.S. public diplomacy to renewable energy.

From 2013 to 2017, Rufus served as the U.S. Ambassador to Denmark where he led efforts to address the effects of climate change, build international coalitions, and invest in clean energy. He was awarded the Grand Cross of the Order of the Dannebrog by Her Majesty Queen Margrethe II of Denmark for his meritorious service.

His pioneering tenure as Ambassador has been profiled in the Wall Street Journal, the Atlantic, CNN, and Vice News, among many other national and international outlets, and he has spoken extensively across Europe and the United States about his efforts to break down walls and humanize the work of government

At home, Rufus was the National Finance Director for President Barack Obama's 2012 re-election campaign, responsible for the record-breaking $1 billion budget. During Obama's first term, Rufus was the National Finance Director at the Democratic National Committee and supported passage of a number of Obama policy initiatives. Before that, he was an aide on Obama's historic 2008 presidential campaign.

Anders Christian Nordstrøm will give a speech on P2X.

Anders Christian Nordstrøm is Vice President of Hydrogen and oversees all hydrogen and P2X activities at Ørsted. He is a member of the Ørsted's Commercial Executive Committee and joined Ørsted in 2006. Anders Christian Nordstrøm has been involved in the transformation of Ørsted from one of the most coal intensive utilities in Europe to a global leader in green energy. He started working with CO2 strategy and CCS projects followed by various management positions related to the conversion of Ørsted's combined heat and power stations from coal to sustainable biomass and the turn-around of the business unit. In 2021, Ørsted was, for the third consecutive year, named the most sustainable energy company in the world.

Liliana N. Proskuryakova will give a speech on The future of renewable energy and a renewable energy system in Russia.

Liliana N. Proskuryakova is Deputy Head and Leading Researcher at the Science and Technology Studies Lab of the National Research University Higher School of Economics (HSE, Russia). At HSE, Dr Proskuryakova specializes in energy studies, science and technology policy and international cooperation in research and innovation. She also lectures at the MA programme 'Governance of Science, Technology and Innovation'. She holds an MA degree in International Relations and a PhD in Political Science. Previously, she worked as the Head of Governance Unit at the UNDP Moscow Office and think-tanks. She also served as a member of the Seoul Institute of Technology (SIT) International Advisory Board (2020-2021), BRICS Russia Expert Council (2020), Research Committee of the Russian National Committee of the World Energy Council, other expert bodies and foundations.

Claudia Kemfert will give a speech on Corona crisis: Chance for decentralized energy system transformation with full supply from renewable energies.

Claudia Kemfert is head of the Department of Energy, Transportation and Environment at the German Institute for Economic Research in Berlin (DIW Berlin) and Professor of Energy Economics and Energy Policy at Leuphana University. Her research focuses on the economic assessment of climate and energy policy strategies. As reviewer and policy consultant, Claudia Kemfert is a member of numerous sustainability advisory boards and commissions, among others, the German Council on the Environment. In the High Level Group on Energy and Climate, she advised EU President José Manuel Barroso and act in diverse scientific advisory boards. Claudia Kemfert is also a member of several juries as the German Sustainability Prize as well as the German Environment Prize.

Poul Skjærbæk will give a speech on Unlocking the Green Hydrogen revolution at the sea.

Poul Skjærbæk is the Chief Innovation Officer within Siemens Gamesa Renewable Energy dedicated to bring down the cost of wind energy through radical innovations. After working more than 23 years in R&D and technology within the wind business Poul has got a profound understanding of bringing new technologies to market and create value for the customers. Today Poul serves primarily as the Chief Innovation Officer of the Siemens Gamesa Service business unit. Lately he has in addition taken on the role as the technical lead of the green hydrogen efforts within SGRE to accelerate the company's engagement in the energy transition. Poul holds a Ph.D. in Structural Dynamics from Aalborg University and a Graduate Diploma in Business Administration from Aarhus University. Further Poul served as Visiting Research Fellow at Princeton University as a part of his studies.

Abstracts Plenary Keynotes

Plenary Keynote: Rufus Gifford

Former U.S. Ambassador and current Nominee for Chief of Protocol for the United States

The new climate policies under the Biden Administration and the global challenges for the Paris Agreement

The American journey on climate and renewable energy has been a rocky one. As the political dynamic domestically has shifted right, left, right and back again, I know many folks around the world wonder whether the Americans and the Biden Administration will lead on climate like we saw under Obama with a massive investment in renewable energy and global leadership, like we saw with the Paris Agreement, or whether we will revisit a chapter like we saw under Bush where we turned our back on Kyoto or under Trump when we pulled out of Paris and investment in renewable energy was routinely mocked - who can forget “windmill cancer?”

While the political dynamic has changed and evolved, what was happening in American states and cities - together with private sector and NGO leaders - was the development of a firm understanding of our challenges and belief system that sustainability and investment in renewable energy was not only vital for the survival of the planet but also good for business.

This development together with the leadership of the Biden Administration and their commitment to be the most progressive and forward leaning administration in history on climate, the next decade will be a very exciting time for climate investment in the United States. And while there are real hurdles remaining, right now we have every reason to be extremely bullish about the future of American renewable energy.

Plenary Keynote: Anders Christian Nordstrøm

Vice President of Hydrogen at Ørsted

PTX potential for 2050 net zero

With EU net zero targets for 2050 will focus naturally increase on the hard to abate sectors such as aviation, shipping and heavy transport. With decreasing cost of electricity production based on renewables power to X (PtX) has become an interesting tool for these sectors. For these sectors hydrogen, ammonia, e-methanol and e-kerosene could be relevant PtX-products to focus on. Ørsted is working on projects where offshore wind production is combined directly to production of PtX for these sectors. Offshore wind has a relatively stable electricity production and learnings from how to ensure a stable production of PtX-products is important part of the first projects. Also the system-aspects of integrating an electrolyser directly to the wind turbines at transmission level is some of the learnings that we expect to get out of the projects. In this presentation Anders Nordstrøm will elaborate on the potential for PTX to the decarbonisation of Europe, but also on the barriers and challenges that we se in DK and Europe.

Plenary Keynote: Liliana Proskuryakova

Deputy Head and Leading Researcher at the Science and Technology Studies Lab of the National Research University Higher School of Economics (HSE, Russia)

The future of renewable energy and renewable energy systems in Russia

Russia remains a key player on the global energy markets. In 2015, after oil prices fell, the country increased oil production to a record 534.081 bn tons. However, relying exclusively on the fuel and energy sector will not lead to the achievement of sustainable and dynamic economic growth. The national forecasts show that the energy industry's contribution to GDP is likely to drop twofold: from 31% in 2015 to 13%-15% in 2040. Likewise, the industry's contribution to the country's consolidated budget will drop from 30% to 14%-18% during the same period. Therefore, the country has to search for new growth drivers for economy and energy industry. A shift to green growth requires stepping up innovation activity, diversifying the economy and energy sources.

Historically the Russian energy industry has been following a conventional development path. The availability of large hydrocarbon reserves (natural gas, oil, and coal) and water resources has turned into a significant barrier hindering the advancement of safe and efficient alternative energy sources. The innovative activity of Russian companies and those in the energy industry is only 9.9% and 10.9%, respectively. Moreover, until 2015, the country had no renewable energy support schemes. In addition, only a decade ago, the renewable energy technologies were not mature enough for profitable exploitation in most Russia's regions.

Scenario and market analysis shows that renewables could reach grid parity in Russia in 2035. Russian extractive industry companies will have to diversify and restructure. Grid companies should improve relay protection, automation, and accident prevention systems, given the growing share of distributed power plants. Russia's membership in IRENA and WEC, close cooperation with OECD and other international bodies in green energy and climate response opens direct access to the best relevant international R&D practices and their application. The establishment of the renewable sector before the pandemic and the first success stories laid the foundation for future development.

The COVID-19 pandemic had some adverse effects on the global and national energy industry, including renewables. The visionary future for the Russian renewable energy sector includes qualitative (structural) changes in the industry: full decommissioning of old power plants, radical reduction of coal-fired generation, and launching an ambitious modernization program. It will be possible to undertake these steps with a favorable external environment - technology cooperation with other countries, lower cost of credit, and economic recovery. Green digital transformation of the electric power industry implies close links with other energy segments and other sectors of economy (i.e. e-mobility, smart homes, etc.). New cross-sectoral solutions have to be put in place and benefit energy, construction, transport, water supply and sanitation, and other sectors.

Plenary Keynote: Claudia Kemfert

Professor of Energy Economics and Sustainability and Head of the department Energy, Transportation, Environment at the German Institute of Economic Research (DIW Berlin) since April 2004. She is a member of the German Advisory Council on the Environment.

Corona crisis: Chance for decentralized energy system transformation with full supply from renewable energies

What the current corona crisis makes evident once again is that in times of crisis, systemic relevance and resilience are very important. Energy system transformation is the solution to both challenges: a successful energy system transformation that guarantees a full supply of domestic renewable energies is systemically relevant and creates enormous economic resilience; it makes us independent of external negative shocks. What's more, it strengthens regional value creation, promotes innovation and enhances the competitiveness of the entire economy. A full supply of renewable energies is technically feasible and economically profitable. The New Start of the Corona Crisis can be a chance to solve all crisis. Climate protection is the way out of the crisis. Climate protection is the engine of the economy and creates jobs, whether in the field of low-emission energy technologies, as demonstrated by the renewable energy sector, but also sustainable mobility, climate protection technologies, energy or financial services.

Readings:

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Plenary Keynote: Poul Skjærbæk

Chief Innovation Officer, Siemens Gamesa Renewable Energy

Unlocking the Green Hydrogen revolution at the sea

The IEA predicts that the world will need to install 850 GW of Electrolyser capacity by 2030 and 3600 GW by 2050 to stay below 1.5 degree warming. This amount of electrolyzers will require even more GW of renewable energy and the achievement of green hydrogen producton at scale is thus dependent on a large share of offshore wind energy. In this keynote, Poul Skjaerbaek will present Siemens Gamesas innovation work to bring hydrogen conversion to turbine level. This means producing hydrogen at each individual turbine to lower electrical losses and to modularize a wind-to-hydrogen system that can bring green hydrogen to cost-parity by 2035.

Lorenzo Cassetti is a junior engineer graduated in October 2020 in Energy Engineering at Politecnico di Milano. His Master Thesis subject is a Thermal Energy Storage pilot plant analysis developed in Vienna at TU Wien (through the Erasmus project). He currently work as intern in a consultancy firm.

Realization and energy assessment algorythm of a Horizontal Packed Bed Regenerator for Thermal Energy Storage

Lorenzo Cassetti, Politecnico di Milano

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The scope of the thesis is to present the activities performed to realize the test rig, built in Technische Universität Wien facilities by the Institute of Energy and Thermodynamics, of a Horizontal Packed Bed Regenerator for TES, and to characterize its energy and thermodynamic performances, providing alternative methods. The main phenomena to analyze in order to make such evaluation are: 1) Temperature gradient thickness and its evolution in relationship with the performed cycles. This phenomenon takes the name of thermocline and determines the thermodynamic efficiency of the sensible TES system in terms, of energy stored during charge and released during discharge. The wider the temperature gradient inside the reactor, the lower the amount of energy storable. 2) Thermal hysteresis, a phenomenon strongly bonded to thermocline thickness consisting in the progressive enlargement of the latter with the number of performed charge-discharge cycles. If not carefully considered and limited, thermal hysteresis could lead to a temperature gradient as large as the reactor itself. In this condition, no heat can be stored. Two different methods have been developed to assess the efficiencies of the test rig: Volumes Method and the Analytical Model. The effects of thermal hysteresis have been assessed through a dimensional analysis, together with the assumptions made concerning storage material thermophysical properties, since they were not available for the specific material used.

Keywords: Thermal Energy Storage, Sensible Thermal Energy Storage, Horizontal TES Regenerator

Mostafa Fallahnejad is an associate researcher at the EEG at TU Wien. He holds a master's degree in Power Engineering from Technical University of Munich (TUM). He is involved in the field of energy system modelling as well as H&C planning.

District heating distribution grid costs: comparison of two approaches

Mostafa Fallahnejad, TU Wien

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The linear heat density (transferred heat per length of pipeline) is a decisive parameter in economic viability of implementing DH system. By introduction of the concept of effective width, Persson and Werner proposed an analytical way of estimating the linear heat density. The greatest advantage of this approach is its simplicity in applying it. This approach was updated in 2019 with a set of new constant factors as well as update of effective width definition for areas with high plot ratios. Despite the fact that the approach is based on the empirical data from Sweden, it has been widely used in for case studies in other countries both in literature and in research projects. In this study, the results obtained by the approach is compared with results of a detailed grid model (DHMIN Model) for two case studies in Romania and Denmark. The outcomes of this comparison will contribute to better interpretation of costs and linear heat densities obtained based on the effective width concept.

Keywords: district heating, distribution grid, effective width, DHMIN

Dr. **Tao Feng**'s research interests include modelling the choice preference of people in urban environment, dynamic models, behaviour change and data-driven technology in transportation. He has been working on various topics including human mobility, smart energy and energy behaviour.

Companies' acceptance of innovative energy facility: Results of a simultaneous equation approach

Gaofeng Gu, Eindhoven University of Technology; Tao Feng, Eindhoven University of Technology; Ad Breukel, Avans University of Applied Science, Research Group Smart Energy, Hugo de Moor, Avans University of Applied Science, Research Group Smart Energy; Brecht Zwaenepoel, WVI

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The popularity of renewable energy depends on the choice of stakeholders, residents and commercial agencies, who need to accept the energy facility in a good balance of cost and benefits. Companies may be bounded in realizing the sustainable goals in their buildings because of property ownership, desire in energy and proved business models, however, to what extent companies intend to accept/install the various innovative energy facility in buildings remains unclear. Existing studies exploring the influential factors on energy facility are mainly based on residential buildings, the acceptance of companies on energy facility has not been addressed sufficiently in the literature.

This study therefore is to investigate the acceptance of companies on innovative energy facility with a specific focus on the interrelationship between multiple alternatives. Due to the possibility various energy technology like solar panels, heat pumps, and ventilation may be interdependent, e.g. a choice of ventilation may increase the necessity of solar panel to cover its energy consumption, in this study, we designed an orthogonal design for the stated choice experiment in which entrepreneurs were invited to make a choice among solar panel, heat pump and innovative ventilation according to the attributes provided. A simultaneous equation model was estimated to analyse the influencing factors on the acceptance behaviour and the correlations between different energy facility.

Keywords: Company acceptance; Innovative energy facility; Solar panel; Heat pump; Ventilation

Kirstin Ganz is a research associate at FfE GmbH. After completing her bachelor's degree in mechanical engineering and her master's degree in energy technology at RWTH and Dalarna University, she has been working at FfE GmbH since 2018, focusing on modeling, and forecasting methods.

How can energy system modeling electricity prices be adjusted to reflect real price spreads for flexible assets in the future?

Kirstin Ganz, Timo Kern, Serafin von Roon, Forschungsgesellschaft für Energiewirtschaft mbH

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With increasing capacities of volatile renewable energy sources (RES) the demand of flexible assets to balance the volatility of RES increases. The diffusion of the different flexible assets depends mainly on economic aspects. Therefore, more and more business cases arise such as smart or bidirectional charging of electric vehicles, demand side management in industry or the smart, price-dependent use of heat pumps. To evaluate these new business cases for the future energy system, energy system modeling prices are being used. However, these are only an approximation of real electricity prices and tend to underestimate the real volatility of the electricity price. As a result, the calculated revenues of flexible assets are significantly lower in the optimally modeled energy system than expected from historical data. To address this problem, as a first step, the authors identify and classify the deviations between modeling prices and historical prices and allocate these deviations to influencing technologies or model simplifications. The price deviations are partly addressed in the model and partly in an ex-post adapting function. The suitability of the approach for determining the revenues of flexible assets is evaluated using relevant statistical indicators such as the standard deviation of the daily hourly electricity price of a day. We show that both model endogenous and model exogenous adjustments can improve the evaluation of the revenues of flexible assets.

Keywords: energy system modelling, flexible assets, busines case for flexible assets, modeled electricity prices

With a background in Physics and Energy Engineering, **Regina Hemm** started to work as a Junior Research Engineer at the AIT in 2018. Her main tasks focus on the integration of flexible units in various electricity markets by using techniques of linear- and mixed integer programming and optimization.

Optimization of the bidding strategy of a virtual power plant by participating in short-term, balancing- and redispatch markets

Regina Hemm, AIT Austrian Institute of Technology GmbH; Ksenia Poplavskaya, AIT Austrian Institute of Technology GmbH; Stefan Strömer, AIT Austrian Institute of Technology GmbH

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Renewable energy resources can provide a valuable flexibility potential for multiple markets and grid services in the future. The project "REgions" focuses on the development of algorithms for an optimal dispatch and bidding of a renewables-based virtual power plant (VPP) by considering current short-term and balancing market conditions, as well the introduction of a potential redispatch market. In this paper, the focus of this work lies on the comparison of different pricing and bidding strategies for a redispatch market and the analysis of their feasibility. We answer the questions of 1) which pricing models and remuneration mechanisms for redispatch are the most attractive for renewables-based VPPs using current cost-based redispatch as a benchmark; 2) whether pre-curtailment of PV is economically sensible and how much influence does the call probability of redispatch, and balancing energy have on the bidding behaviour of the VPP. Extensive simulations of the bidding behaviour of a photovoltaic power plant or several plants within a VPP providing symmetrical dispatch are carried out using linear optimization techniques. The paper describes the algorithms developed for aggregation, scheduling, and energy management, as well as the assumptions and results for a combined participation of a PV-VPP market rules in redispatch-, balancing- and short-term electricity markets. The bidding behaviour and the possible revenues in these markets are evaluated and compared.

Keywords: Portfolio optimization, redispatch, balancing, electricity markets, pricing schemes, VPP, market participation

Jin Hur's research interests are in all areas related to integrate high level of renewable generating resources into smart energy systems. He has performed many industrial research projects with the KEPCO and KPX on flexibility solutions for smart energy systems.

A practical metric to evaluate the ramp events of wind generating resources to enhance the security of smart energy systems

EunJi Ahn, Ewha Womans University, Jin Hur, Ewha Womans University

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As the environmental pollution becoming more serious around the world, wind power is getting attention and playing an important role in power supply because of its eco-friendly features. However, the large variability and uncertainty of wind power generation is still a key problem that needs to be solved. There, we analyze the characteristics of ramping event to make an accurate wind power forecasting. The rapid increase and decrease in wind power, which exceeds a certain percentage of the rated power within a short period of time is called ramp. Metrics for evaluating its magnitude and duration can help energy system operators drive and prepare the reserve requirements needed to compensate for the ramp. In this paper, we propose the practical metric to evaluate the ramp events of wind generating resources. The ramping events is analyzed and characterized by the following features: ramping start/end, ramping magnitude, ramping duration, ramping rates in Jeju Island. The ramping events of wind generating resources will be quantified by the proposed metrics to make an improvement in economics and security of the smart energy system.

Keywords: Ramp Event, wind power forecasting, wind generating resources, security, smart grid, smart energy system

Thanh Huynh is pursuing his PhD in collaboration with Siemens AG and TU Darmstadt, doing research on multi-modal energy markets. Prior to his time as PhD student, he graduated with a master's degree in electrical engineering from RWTH Aachen University.

Local Energy Markets for Thermal-Electric Energy Systems considering energy carrier dependency and energy storages

Thanh Huynh, Siemens AG; Pascal Friedrich, TU Darmstadt; Sebastian Thiem, Siemens AG; Martin Kautz, Siemens AG; Stefan Niessen, Siemens AG, TU Darmstadt

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In this paper we describe a multi-modal Local Energy Market in which thermal energy of district heating systems is coupled with a local electricity market. Considering the ongoing energy transition, the integration of volatile renewable energy sources is a continuous challenge, whereas, in thermal systems, the demand for low-carbon heat supply is increasing. A market-based coordination of thermal-electric energy systems is a potential answer to the prevailing problems of both sectors. The underlying principle is that commodities of multiple energy carriers are coordinated through a central aggregator which emphasizes spatial proximity of supply and demand. An adequate representation of energy-mode coupling assets, i.e. heat pumps, is achieved by using interdependent sets of market orders. This enables an explicit interlink of thermal and electric energy carriers, allowing cross-energy load-shifts. In addition, complimentary storage orders are introduced to incorporate flexibilities of energy storages into the market. Appropriate network models are applied to validate the physical viability of the market results. The Local Energy Market is compared in a case study to a business as usual scenario to illustrate limitations and benefits of the proposed market design. Among others, the results lead to the conclusion that Local Energy Markets can improve the self-sufficiency of local electric systems and decrease peak loads in thermal energy systems.

Keywords: Local energy market, Market design, Flexibility market, Sector coupling, Storages, Local energy system, Multi-modal energy system, Prosumers

Jiao Jiao works as data scientist at the Fraunhofer Institute for Systems and Innovation Research in Karlsruhe in the Competence Center Energy Policy and Energy Markets. Her research focuses on smart buildings and their user behaviors based on text mining, machine learning and visual analytics.

Text Mining based Identification of Emerging Technologies and Business Models for Smart Energy Systems

Jiao Jiao, Fraunhofer Institute for Systems and Innovation Research ISI; Yuwei Wang, Daimler AG

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With the growing prevalence of artificial intelligence (AI), a new era of smartness is ushered in both technology and business model. Identifying emerging technologies and business models is crucial for the energy sector to enhance energy efficiency and gain first-mover advantages in the market competition. Compared with publication and patent databases, Twitter and news provide the first-hand technologies and business models in practice, which bridges the gap from research to the market. Thus, this paper proposes a novel framework for detecting emerging technologies and business models from Twitter and online news by iterative web scraping and text mining. First, keywords are extracted from PatBase database by Rapid Automatic Keyword Extraction algorithm. With the basic keywords, texts from Twitter and Nexis news database are scraped iteratively. Second, all the Tweets and news are clustered into different topics and sub-topics by our hierarchical Biterm topic model. In the end, a time series visual analytics is applied to discover the trending technologies and business models. Germany is selected as our case study. Among 659985 Tweets and 262793 news, 154 emerging technologies and business models are identified, where photovoltaic is the most trending topic. Demand response and power warm coupling are the most popular techniques in the energy domain; AI and big data also take a large share of discussion. Tenant electricity is the most promising business model.

Keywords: smart energy systems, technology identification, business models, text mining, visual analytics

Figure 1: Our analysis workflow with iterative data collection

Dr. **Nicola Kleppmann** is a Physicist. She has been employed with the electronics company KT Elektronik since 2015 and is General Manager since 2021. KT Elektronik develops and produces devices and software solutions for the optimal use of district heating.

ML4Heat - Tools for the optimized operation of existing district heating networks based on machine learning methods

Nicola Kleppmann, KT Elektronik GmbH; Benedikt Hartung, KT Elektronik GmbH; Steffen Wallner, Fraunhofer IOSB; Naga Mamatha Gonuguntla, Fraunhofer IOSB; Thomas Bernard, Fraunhofer IOSB

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The increasing trend towards smart metering in district heating networks (DHNs) makes the networks more transparent than they have ever been. Previously the consumer side was autonomous, and the network was optimized based on the experience of a few plant operators. The global objective of the ML4Heat project is the development of methods and software tools to optimize the operation of existing DHNs from an energetic and economic point of view. Meter, controller, and plant data is evaluated using machine learning processes on three levels:

1. Individual substations: Tools for performance monitoring and optimizated control of substations are developed and implemented. These range from detecting and where possible repairing anomalous behaviour to minimizing return flow temperatures without the use of additional sensor.
2. Strand optimization: Methods are being developed which, based on the measurement data from the district heating transfer stations, can quickly identify anomalous behaviour of subsections (strands), such as high heat losses. For this purpose, machine learning processes are used in combination with basic physical equations.
3. Network optimization: First, methods have been developed to predict the energy demand for the entire district heating network more precisely than before. This uses only readily available data and allows for the optimization of the power plants under consideration of heat losses, supply delays and individual consumer patterns.

Keywords: Smart metering, IoT platform, machine learning, artificial intelligence, condition monitoring, strand optimization, network optimization

Kevin Knosala is a PhD candidate at Forschungszentrum Jülich. He holds a M.Sc. in Mechanical Engineering and Business Administration from RWTH Aachen and a Diplôme d'Ingénieur from École Centrale Marseille. His current research focuses on decarbonization pathways for urban energy systems.

Generic Input Generation for Residential District Energy System Models from Open Data for Germany

Kevin Knosala, Noah Pflugradt, Julian Reul, Thomas Grube, Peter Stenzel, Leander Kotzur, Detlef Stolten, Forschungszentrum Jülich, RWTH Aachen

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A common problem for district energy system models is the collection of realistic input data. This covers parametrization of building energy characteristics and the demographic structure of the district and related demand and generation time series. Substantial need for manual gathering and editing of input data hinder the transfer of methodologies and results from one district system to another as well as scaling to a larger context. Approaches that use openly available data such as Open Street Map for building characteristics or standard load profiles for the energy demand cannot adequately represent the characteristics of the real system. We present a methodology to create input data for residential district energy system models from open data in a generic way that is agnostic to the location and size of the considered system. We are using openly available 3D building and weather data in combination with socio-economic census statistics and prevalent urban building typologies to parametrize the thermal building hull and simulate household energy demand profiles for electricity, heating and cooling as well as renewable generation profiles from rooftop PV and geothermal energy at a building level. Further, transport demands of the households are derived from national statistics and forecasts. The presented approach creates building specific demand datasets for arbitrary groups of buildings in Germany and can be used as input for residential energy system analyses.

Keywords: input generation, generic, residential, building, district, energy system model, open data, GIS, statistics, census, cityGML

Lukas Kranzl is working as a senior scientist and team leader at the Energy Economics Group at TU Wien. He has around 20 years' experience in research on future perspectives of sustainable energy systems with a focus on heating and cooling, scenario development and analysis of policy instruments.

The economic potential of district heating under climate neutrality: the case of Austria

Lukas Kranzl, TU Wien; Mostafa Fallahnejad, TU Wien; Jeton Hasani, TU Wien; Marcus Hummel, e-think

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District heating and cooling has a high potential to supply efficient heating and cooling and thus contribute to the decarbonisation efforts. The Energy Efficiency Directive asks EU Member States to carry out a comprehensive assessement of the potential of efficient heating and cooling. The research questions of this paper are: What is the economic potential of renewable district heating under different scenarios for the case of Austria? How do decarbonisation targets affect the way how cost-benefit analyses foreseen in the comprehensive assessment should be applied? We carried out following steps: (1) Based on existing scenarios of future energy demand in this sector, we derived heat density maps, resulting heat distribution costs and potential district heating areas. (2) These areas were clustered into 10 region types. For each of them, district heat supply portfolios were assessed with an hourly dispatch model. (3) Through identifying the least cost portfolios and comparing them with the costs of individual heat supply options, we derive economic heat supply mixes for Austria. Depending on the assumed parameters, the economic district heating potential varies between 10% and 50% of the space heating and hot water demand, with the connection rate being the main driver. Under none of the assumed price scenarios, renewable gas turns out to be an economically viable option for extensive application, neither in district heating nor in individual heating systems.

Keywords: District heating potentials, climate neutrality, scenarios, energy efficiency directive, cost benefit analysis

Jacopo de Maigret has completed a Master in Energy Engineering at the University of Trento, with a thesis investigating the decarbonization scenarios for industrial energy supply through multi-objective optimization. Currently working as a junior researcher at Fondazione Bruno Kessler, Italy.

A multi-objective optimization approach in defining the decarbonisation strategy of a refinery

Jacopo de Maigret, Fondazione Bruno Kessler; Diego Viesi, Fondazione Bruno Kessler; Md Shahriar Mahbub, Ahsanullah Univeristy of Science & Technology; Matteo Testi, Fondazione Bruno Kessler; Cuonzo Michele, Sonatrach Raffineria Italiana S.r.l. - Raffineria di Augusta; Jakob Zinck Thellufsen, Aalborg University; Poul Alberg Østergaard, Aalborg University; Henrik Lund, Aalborg University; Marco Baratieri, University of Bozen-Bolzano; Luigi Crema, Fondazione Bruno Kessler

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The 2030/2050 European climate and energy targets will result in increasingly stringent free emission allowances and higher CO2 cost for the industrial sector. For this reason, defining a decarbonisation strategy is crucial when planning industrial development. In this work, the case study of an Italian refinery is proposed. The methodology involves the coupling of EnergyPLAN with a Multi-Objective Evolutionary Algorithm (MOEA), considering the minimization of annual cost and CO2 emissions as two potentially conflicting objectives and the energy technologies' capacities as decision variables. This approach has previously been applied in local, regional and national energy systems; however this is the first case study in the industrial sector. For the target year 2025, EnergyPLAN+MOEA has allowed to model a range of 0-100 % decarbonisation solutions characterized by optimal penetration mix of 22 technologies in the electrical, thermal, hydrogen feedstock and transport demand. A set of 9 scenarios, with different land availabilities and implementable technologies, each consisting of 100 optimal systems out of 10000 simulated ones, has been evaluated. The results show, on the one hand the possibility of achieving medium-high decarbonisation solutions at costs close to current ones, on the other how the decarbonisation pathways strongly depend on the available surface for solar thermal, photovoltaic and wind, as well as the presence of a biomass supply chain in the region.

Keywords: Smart Energy Systems, Multi-Objective Evolutionary Algorithm, sector coupling, renewable energy, low-carbon refinery

Marko Mimica obtained a Master degree in 2017 from Faculty of electrical engineering and computing in Electrical Power Engineering. He enrolled a PhD in 2018 at Faculty of mechanical engineering and naval architecture where he works as a research assistant mostly on topic of smart energy systems.

A stochastic model for smart energy systems analysis

Marko Mimica, Goran Krajačić, Faculty of mechanical engineering and naval architecture University of Zagreb

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Smart energy systems are a crucial element for the successful decarbonisation of energy systems. Numerous studies that prove the value of smart energy systems were already conducted and this study aims at further enhancement and investigation of positive effects of smart energy systems. The method proposed in this study proposed a stochastic DC OPF model for the quantification of benefits of the smart energy systems that incorporate different sectors. This enables the assessment of sector coupling benefits on power flows in the grid as well as nodal prices in the network. Additionally, the method calculates the results under certain risk as a stochastic approach is considered. The case study for the proposed method is conducted on the case study of Croatia. The case study is based on the results of the project INSULAE that showed the benefits when smart energy systems are implemented. The results of this project were obtained on three different islands and this study aims to demonstrate the replication possibilities of these solutions on the country level. The results showed that integration of different sectors results in lower energy price as well as more efficient operation of the transmission system. The results implicate that smart energy systems increase social welfare as well as improve the operation of the power system in terms of lower operation cost.

Keywords: Smart energy systems, Stochastic modelling, DC OPF, cross-sector integration, energy planning

Adrian Ostermann is a research associate at Research Center for Energy Economics (FfE) since 2018 and holds a M.Sc. in Environmental Engineering from TU Munich. He is currently working on the Project Bidirectional Charging Management where he is responsible for the evaluation of the field trial.

Forecasting charging station occupancy using supervised learning algorithms

Adrian Ostermann, Yann Fabel, Mathias Müller, Research Center for Energy Economics (FfE)

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The National Platform Future of Mobility (NPM) projects up to 10 mil. electric vehicles by 2030 in Germany. In correspondence with EU 2014/94 this development would translate to 1 mil. public charging points (CP). This rising number of EVs and CPs poses new challenges to the energy system on the one hand. Considering the grid, uncontrolled charging of EVs can lead to high peak loads. On the other hand, EV users need to plan charging events more prudently than conventional users due to the different refueling infrastructure. These challenges can be met in part by predicting CP occupancy. The knowledge about the time of occupation or availability of a CP in advance, enables EV users to plan their charging process accordingly. Moreover, network operators and energy managers could enhance predictions about peak loads while energy suppliers could anticipate required energy amounts. Therefore, different supervised learning algorithms to predict occupancy of public and private CP are investigated. Public and workplace CP occupancy prediction is evolved from ACN project. First, we describe the dataset and perform feature engineering. To prevent overfitting and evaluate model performance in a more robust way we use time series cross-validation to obtain test, training, and validation sets. Different supervised learning algorithms are then applied and optimized by hyperparameter tuning. The models are finally compared with different performance metrics on variable forecasting periods.

Keywords: supervised learning, charging point, forecasting, occupation

Martin Lindgaard Pedersen started at LOGSTOR in 2019. Until 2021, he was responsible for Innovation, now Responsible for Digitalization. He is currently looking into how digitalization can benefit and support customers in the green transition. He is responsible for a roadmap with a range of different digital initiatives within tools and technologies.

Digital tools for refurbishment planning based on facts and choice of pipe system based on Total Cost of Ownership and CO2 emission

Martin Lindgaard Pedersen, Peter Jorsal, LOGSTOR A/S

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A digital tool for refurbishment planning:
There are pre-insulated district heating pipes in the ground for billions of euro, and the efficiency and security of flawless supply is important for the green transition of the future energy systems. The condition of these pre-insulated pipes depends on the age, quality of installation, the general handling, water quality, type of products, the underground conditions, surveillance system, operation of the system and other factors. On the top of that, the insulation properties of the old pipes might not live up to today's energy efficiency requirement. So, the key question is where to start when renovating old pre-insulated pipes? Where will the energy company get the best return of investment and get the best long-term plan?

LOGSTOR is developing a tool that will help the energy company plan and prioritize their renovation. The tool will calculate the budget needed in order to maintain or even improve the quality of the system.

A digital tool for making the right choice of pre-insulated system:
LOGSTOR is developing a digital tool which based on customer and project specific parameters will calculate possible solutions for the pre-insulated pipe system and propose the system with the lowest Total Cost of Ownership (CAPEX and OPEX) including the cost of CO2 emission. The tool will as well calculate the CO2 emission related to the heat loss for all solutions for the pre-insulated pipe systems.

Keywords: Pre-insulated pipe, Energy Efficiency, Digital tool, Refurbishment plan, Renovation of old pipes, Total Cost of Ownership, CAPEX, OPEX, Heat loss, CO2 emission, Energy Company, insulation property

Tim Pedersen is a Ph.D. student at Aarhus University under the group Renewable Energy & Thermodynamics lead by Gorm B. Andresen. His work focuses on quantifying the flexibility and choices to be made as the European energy system is transitioning towards carbon neutrality.

Modeling all alternative solutions for highly renewable energy systems

Tim T. Pedersen, Aarhus University; Marta Victoria, Aarhus University; Morten G. Rasmussen, Aalborg University; Gorm B. Andresen, Aarhus University,

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As the world is transitioning towards highly renewable energy systems, advanced tools are needed to analyze the increasingly complex energy networks. Energy system design is, however, challenged by real-world objective functions consisting of a blurry mix of technical and socioeconomic agendas, with limitations that cannot always be clearly stated. As a result, economically suboptimal solutions will likely be preferable. We present a method capable of determining the continuum containing all economically near-optimal solutions. A model of the European electricity system is used to validate the developed method. The model uses a 1 node per country topology with hourly temporal resolution. A 95% CO2 reduction constraint compared to 1990 emissions is enforced, while allowing for a 10% increase in system cost. Studying 500.000 samples, the near-optimal region is found to be relatively flat with variations among the total installed solar PV and wind capacities covering ranges wider than 1TW, with average values around 1.1 and 0.8TW for solar PV and wind respectively. Among the near-optimal solutions, national self-sufficiency is found to have a strong correlation with installed solar PV and battery capacity. Hydrogen storage has a strong negative correlation with gas turbine capacity. This could indicate that hydrogen storage and gas turbines can be used interchangeably as backup capacity for periods of scarce renewable energy resources.

Keywords: Modeling to generate alternatives, Uncertainty analysis, Energy system optimization models, PyPSA, Renewable Energy, Decarbonization, Self-sufficiency, Transmission, Land-use, Flexibility,

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

Bottom-up method to derive Cost curves for heat savings in buildings for all European countries

Matteo Giacomo Prina, Ulrich Filippi Oberegger, Roberto Lollini, Wolfram Sparber, EURAC Research, Institute for Renewable Energy

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In the European Union, space heating accounts for around a quarter of the final energy consumption. The European Green Deal aims to reach the climate-neutrality by 2050. The scope of energy system modelling is to develop energy scenarios to support policy-makers in the definition of an energy strategy to achieve such goal. Energy system models typically lack a robust methodology to implement energy efficiency within the building sector. Cost curves for heat savings in buildings are instruments typically used for this scope. However, their implementation is delicate due to the high need for data: building stock characteristics such as specific energy consumption, heated surfaces and costs database for the different refurbishment measures. In this paper a methodology to derive Cost curves for heat savings in buildings starting from open data is presented. The main open data source is the HOTMAPS project findings. Moreover, this methodology is applied to the EU-27 countries and the different cost curves for each of them are presented. The aim is the creation of a tool to support energy system modellers in the implementation of energy efficiency in buildings within the energy scenarios development process.

Keywords: Cost curves, Energy retrofit, Energy refurbishment, Energy scenarios, Energy planning

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

What can past examples teach us about the rollout and scale-up of smart energy systems?

Dr. Callum Rae, Dr. Sandy Kerr, Prof. M.Mercedes Maroto-Valer, Heriot-Watt University

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As the transition towards a more sustainable, distributed energy model continues to gather pace, the number of deployed Smart Local Energy Systems (SLES) projects has increased. Ranging in age, size, location and complexity, these projects have faced a series of technical, social and economic challenges, with varying degrees of success. As such, these deployed projects represent significant – and often under-utilised – sources of practical experience and expertise that can inform the design, development, operation and regulation of SLES in future.

This research aims to capture this latent expertise and feed it back into the current academic, industry and policy environment to help mitigate barriers to adoption and scale-up. This is achieved using a range of case studies of existing multi-vector SLES in the UK, strategically selected to demonstrate the complexity and variation which exists within the sector and the multitude of challenges faced. Case studies consist of in-depth desktop reviews and semi-structured interviews with key project stakeholders, with the aim of cataloguing and understanding the barriers faced and the implications for future scale-up.

This paper presents the findings of these case studies and discusses their wide-ranging implications for the scale-up and future development of SLES. These include the need for improved knowledge sharing practices and for a reappraisal of how upscaling is viewed and promoted by both project funders and policy makers.

Keywords: Case studies, smart local energy systems, upscaling, barriers

Morten Karstoft Rasmussen has a background in nanoscience and physics from Aarhus University, and is now employed as a Data Scientist in the Analytics Team at Kamstrup, focusing on digitalization within district energy.

Connecting the DH value chain with smart meter data

Morten Karstoft Rasmussen, Steen Schelle Jensen, Kamstrup

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Data-driven solutions and services to connect the entire district heating value chain from production to buildings and end-users, and vice versa, becomes increasingly important to enable the transition towards flexible and low-temperature 4DH systems. Digitalization is key to enable integration of renewables and waste heat, to ensure security of supply in an energy efficiency context and not at least to make district energy an attractive offering to the ends-users.

As smart meter data, in near real time, and with high temporal resolution (hourly or maybe even higher), becomes readily available for more and more utilities, new improved tools for processing, cleaning, aggregating, analyzing and visualizing these data becomes more important, and new analytics tools and approaches are being developed in close collaboration with forward-looking utilities, academia and other domain experts.

One example could be an application combining data from all heat meters in the network, together with GIS and SCADA data, to estimate and visualize how temperature propagates both spatially and temporally in a district heating network. In this way, the network operators can gain important knowledge on how the energy travels in the network from day to day, and in various operation scenarios, like for instance during winter and summer periods.

Keywords: Digitalization, analytics

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.

District heating systems modelling: A gamification approach

Dmitry Romanov, Stefan Holler, HAWK Hildesheim/Holzminden/Göttingen University of Applied Sciences and Arts

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District heating (DH) is supposed to largely contribute to achievement of the climate goals in the near future. However, public awareness, understanding and acceptance of the technology are required. At the same time, gamification has been identified as a viable teaching and learning method in higher education, which might be also appealing to non-professionals and might bridge their knowledge gap in DH. Since literature review has shown that no game about DH exists, the concept of a serious game about a heat supply system and its transformation from a fossil fuel-based system to a renewable-based one is introduced in this work. The first results of the game development are presented, namely, initial conditions, gameplay, the model of heating sector and the model of the DH transformation. The game will allow players to explore interdependencies between technical, economic, ecological, and sociopolitical aspects as well as among different stakeholders (producers, consumers, government) and develop strategies for a successful transformation. The flexibility of different transformation scenarios and the influence of boundary conditions on the transformation can be analyzed after playing the game multiple times.

Keywords: gamification, serious games, district heating, energy transition, decarbonization, public awareness, public acceptance

Costanza Saletti is a Postdoctoral research fellow at the Center for Energy and Environment (CIDEA) of the University of Parma, Italy. Her research interests are related to the simulation, optimization and smart control of complex energy systems and district heating and cooling networks.

A hierarchical control algorithm with yearly and daily horizons for optimally managing district energy systems

Costanza Saletti, Mirko Morini, Agostino Gambarotta, University of Parma

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Digitalization is one of the factors that are contributing most to the development and decarbonization of the energy sector. In particular, the automation of multi-energy systems supplying heating and cooling networks by means of intelligent management strategies appears promising, as it leads to optimal use of resources, lower cost, and efficient integration of different energy carriers. However, real-time operational optimization of complex energy systems is feasible only on a short time-scale due to the large number of interacting variables, thus it does not include long-term factors such as incentives and year-based constraints. In order to address this research gap, this work proposes a novel multi-time and multi-space scale control architecture which is able to manage a smart district energy system in a holistic way. It comprises three coordinated optimization levels, each periodically updated through the receding time horizon strategy: a long-term supervisory module performs yearly optimal scheduling accounting for long-term aspects and calculates the constraints for a short-term supervisory module which, in turn, optimizes the production system operation with a three-day time horizon. The thermal energy demand is predicted and communicated by low-level multi-agent modules which optimize the different portions of the network downstream. This architecture is computationally feasible and effective in considering constraints and disturbances with different timescales.

Keywords: district heating and cooling networks, smart energy systems, polygeneration, smart control, Model Predictive Control, multi-time scale optimization, hierarchical control

Salman Siddiqui is a PhD candidate at the UCL Energy Institute in the area of energy systems modelling. His current research focuses on exploring the benefits of integrating district heating into the UK power system.

District heating and the GB electricity system in a zero-emission scenario

Salman Siddiqui, University College London

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The UK has ambitious targets to reduce greenhouse gas emissions from the power sector and the built environment. A large share of the electricity generation will be from renewable sources. To accommodate the variability of renewable generation, flexibility in the electricity network is critical. District heating networks with heat pumps can be an important vector for low carbon heat delivery by linking the two sectors and enabling the use of large-scale thermal energy storage to provide flexibility for the electricity system. An electricity system model in a zero-emission scenario is devised with a marginal cost method to calculate electricity spot prices. A simulation of district heating with heat pumps and thermal energy storage is then developed and operated with a model predictive control algorithm to optimise operating costs from the electricity spot prices. Both the renewable capacity factors in the electricity system model and heat loads in the district heating model are derived from hindcasted meteorological data. The cases of both district heating as marginal and non-marginal on the electricity system are analysed.

Results show that thermal energy storage of 1% of annual heat load is required to minimise the operating costs of district heating networks in a non-marginal case. The marginal case shows that the integration of district heating with heat pumps and large-scale TES may have profound effects on the electricity system and resulting costs of generation.

Keywords: District heating, electrification, system integration, flexibility

Goran Stunjek defended his MSc thesis in year 2019 and received title mag. ing. mech. In a year 2019/2020 he enrolled the Doctoral study at Faculty of Mechanical Engineering and Naval Architecture. His field of work is related to studying the joint operation of water and energy sectors.

Analysis of hydropower impact in water energy nexus for smart energy systems

Goran Stunjek, Josip Miškić, Goran Krajačić, Faculty of Mechanical Engineering and Naval Architecture, UNIZG

Goran Stunjek (presenter) goran.stunjek@fsb.hr

Following goals to make Europe the first climate-neutral continent, sustainable development of energy and water sector is gaining more recognition in research field. Complex connection between water and energy sectors in current models and frameworks is fostering a greater research of water, energy, food, and environment linkage. However, the research studies state that the heuristic approach is important for maximization of opportunities in both water and energy systems, to increase energy efficiency in the water sector, extract more energy from available water sources, while reducing the negative effect on the environment. As part of the research, actual data on river flows in Croatia were collected, and a comparative analysis was performed with available simulated data from the LISFLOOD model. A model of the energy sector has been created that defines the operation of hydropower plants in more detail. Available water resources are divided into the natural flow of the river needed to account for the environmental approach, the needs for additional sectors such as agriculture and water supply, and the energy sector as the need to provide electricity generation. Forecasts for future hydrologic conditions were observed, and the assumed development of the Croatian energy system was taken into account, which includes new hydropower capacities, but also other energy sources. Also, the impact of new solar and wind capacities on hydropower generation was observed.

Keywords: water-energy nexus, hydropower generation, renewable energy sources, linear programming

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.

General Optimization Guideline for District Heating Networks and its exemplary Application

Anna Vannahme, Mathias Ehrenwirth, Tobias Schrag, Christoph Trinkl, Technische Hochschule Ingolstadt, Institute for new Energy Systems

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Improving district heating networks (DHNs) with low-investment measures ensures their cost- and energy efficient operation in the future and is vital for the energy transition. In an ongoing project optimization measures for DHNs are collected in a catalogue, that acts as the basis of an optimization guideline for district heating operators.
The catalogue combines the results from published studies with results of an ongoing investigation (cf. figure 1).

Figure 1 illustrates the use of the catalogue with the example of adding a central buffer storage. Results from Romanchenko et al. (2018) indicate that for larger DHNs it is economically questionable and energetically not useable. However, it appears to be an appropriate measure for smaller DHNs (Leoni, 2018). The catalogue acts as a guideline by providing concrete steps for the implementation of the respective measure, for example, the rough dimensioning, checking required place, etc. Based on the concrete DHNs, it is shown when it makes sense to implement a measure and how it can be carried out.

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Keywords: district heating network, energy efficiency, low-investment measures, optimization, guideline, heating center

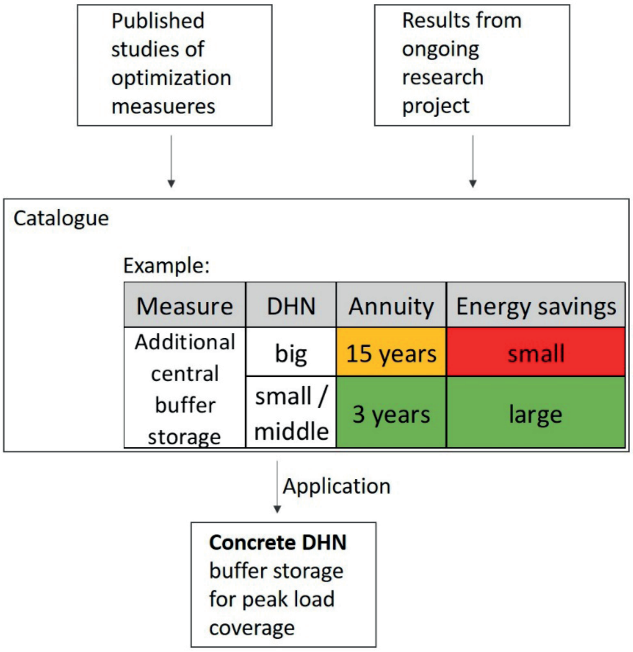

Figure 1. Process of catalog formation and preparation of a guideline through application

Volodymyr Voloshchuk's research is devoted to the development and implementation of exergy-based methodology and tools (including application of Internet technologies) for design, assessment and automatic control of thermal systems.

Exergy-based performance degradation diagnosis for use in digital twins of thermal systems

Volodymyr Voloshchuk, Oleksandr Stepanets, Anastasiya Zakharchenko, Olena Nekrashevych, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"; Oleksandr Pypena, National University of Food Technologies

Volodymyr Voloshchuk (presenter) v.voloshchuk@kpi.ua

During operation the performance of energy systems usually degrades gradually away from the design operation conditions causing additional resources consumptions and economic expenditures. So, detection of such faults and malfunctions is of great practical significance. Among the existing approaches adopted to diagnose the energy systems exergy-based methods provide possibilities to determine the anomalies and to quantify their negative impacts. In order to implement these methods, a mathematical model or simulation of the system is needed. The model should be automatically fitted to current measurements from a real operating system. The paper presents an approach for application of exergy-based performance degradation diagnosis of thermal systems through digital twinning.
The virtual model of a system uses real data for implementation of model-based technique of malfunction identification and quantification. IoT Gateway facilitates device-to-cloud communication. DBMS CouchDB and Time Series Database InfluxDB are proposed for data collecting on Edge level in case of internet disconnection. API, WEB-interface and integration with other components will be developed with Node.js. Cloud CouchDB, InfluxDB and Grafana are proposed for organized collection of data and open source analytics. Python-based simulation program is applied for model development.

Keywords: internet of things, cloud model, database, object-oriented programming, thermal system, exergy-based analysis, diagnosis

David Barns is in the final stage of a PhD focusing on the role of thermal energy storage in the decarbonisation of heat in cities, with a background as a practitioner in local authority district heating efficiency.

Enabling geoexchange in cities: success factors from UK examples

David Barns, Catherine Bale, Alice Owen, Peter Taylor, University of Leeds

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Thermal energy storage (TES) is likely to be integral to a sustainable, secure and affordable energy system facing ever greater challenges in matching supply and demand. Global urbanisation trends mean that TES applications which support decarbonisation in cities are particularly important. Geoexchange TES comprises ground-coupled heat exchangers with ground source heat pumps to use the ground or underlying aquifer as an energy store and balancing mechanism. The technique is established in Europe and the US but remains relatively niche in the UK. To explore sociotechnical factors in the deployment of urban geoexchange, we present the results of a comparative case study exploring residential geoexchange developments in two large UK cities, Leeds and Bristol. We find that whilst both cities share similar climate targets and operate within the same national regulatory framework, active intervention by the planning authority has helped Bristol become a hotspot of urban geoexchange activity in the UK. However this approach carries risks which must be ameliorated for long-term sustainable change. We apply the findings to suggest local policy measures which can help other municipal authorities struggling to meet ambitious carbon reduction goals, and also can help geoexchange practitioners in the UK and internationally to navigate the urban selection environment.

Keywords: Thermal energy storage, geoexchange, cities, 100% renewable energy systems, urban energy transition

Aalborg CSP Product Manager & Senior Engineer, **Morten Vang Bobach** is an experienced Master of Science in Mechanical Engineering from AAU Mechanical Engineer graduate with a profound experience within Pit Thermal Energy Storages (PTES). During the past decade Morten has been involved in all aspects of the PTES technology including research, technology development and business development as well as project management of several PTES installations and district heating projects in general. At Aalborg CSP Morten is involved in the sales, product development and project execution of PTES solutions as well as supporting on thermal storage, energy systems and development in general.

Multi-purpose Pit Thermal Energy Storage in Combination with Heat Pumps

Morten Vang Bobach, Jes Donneborg, Peter Badstue Jensen, Aalborg CSP

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The Pit Thermal Energy Storage (PTES) technology is continuously being optimized for improved performance. Large scale PTES systems are capable of storing large amounts of thermal energy in a cost-efficient way. This is proven in projects in both Denmark and Tibet. In these projects, the PTES systems have all been integrated with either a solar thermal plant or a combination of solar thermal and heat pumps. Not only solar thermal but a variety of energy sources - including excess heat from industry or power production – can be integrated with a PTES for improved flexibility and efficiency. Both PTES and heat pumps are important technologies in the transition to a fossil free energy sector. There are several examples of heat pumps in the Danish district heating sector, where heat is produced efficiently from low-temperature heat sources. PTES and heat pumps are good stand-alone technologies. However, combining the two technologies opens a wide range of new possibilities, added flexibility and even higher efficiency of the energy system. The combination of PTES and heat pumps is well-suited for district heating (and cooling) systems.

In a simple setup, the heat pump cools the storage during winter and uses the extracted energy from the storage to supply district heating. As a result, the annual heat loss in the storage is reduced and the capacity of the storage increased. Moreover, the performance of a connected solar plant can be increased due to the presence of cold return water for the solar panels. Likewise, the cold water can be used to extract additional surplus energy from the industry. By combining the two technologies – PTES and heat pump – the overall efficiency of the system is improved significantly.

More complex solutions and the benefits of combining PTES and heat pumps with energy sources and district heating are proposed. Figure 1 is an example of a setup allowing flexible and efficient use of multiple sources of heat and electricity. This combination of PTES and reversible heat pumps makes it possible to convert electricity to thermal energy, store it long term with low loss and then convert it back to electricity at a low cost. The combination of PTES and heat pumps is then a multi-purpose system.

Keywords: District Heating, Smart Energy System, Thermal Energy, Solar Thermal Power, Heat Pump, Thermal Battery, Thermal Energy Storage, Pit Thermal Energy Storage

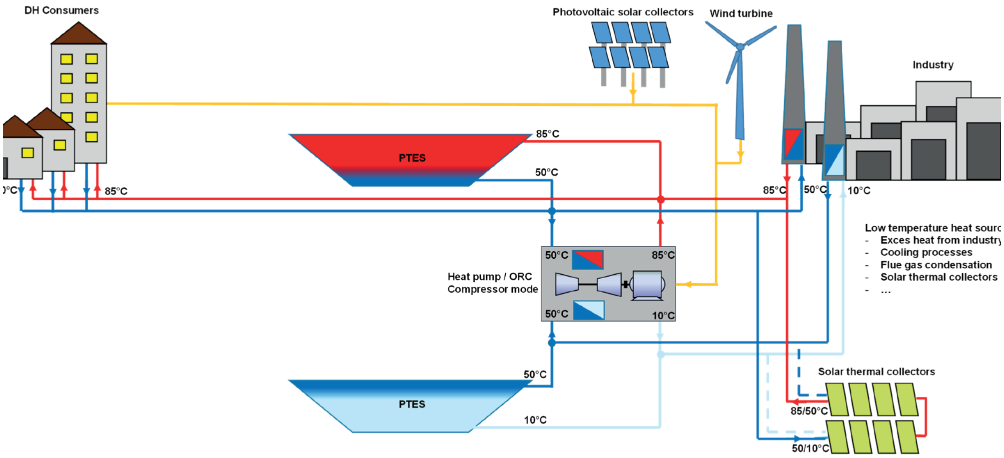

Figure 1: Aalborg CSP Conceptual Multi-Purpose Energy System.

Charles Hansen has 25 years' experience in district heating and cooling, where he has experimented with and installed low temperature district heating grids as well as an energy central that is utilizing waste energy from cooling production combined with ATES systems and seasonal storage.

Reducing carbon emissions through low temperature district heating zones

Charles Hansen, Grundfos Holding

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Grundfos' grid optimization system named iGRID is an innovative solution that makes an effective transition from high temperature to low temperature district heating possible, by dividing the distribution grid into smaller low temperature zones where both the pressure and temperature is adapted to the exact need.

The system collects online data from the district heating grids and use the collected data to optimize both the supply and return temperatures. The grid is split into low temperature zones with pre-built mixing loops and controlled based on real-time data, whereas return temperatures are optimized through service visits to buildings with high return temperatures that is identified by analyzing building heat meters. Everything is connected and remotely controlled by a cloud solution that lives up to all security demands and that can easily be integrated with SCADA systems. The IGRID concept is also able to utilize local low-temperature heat sources and feed the heat energy into the distribution network in a very energy-efficient way by using medium-sized heat pumps.

Grundfos is commitment to support the UN sustainability goals and is developing products and solutions to reduce unnecessary energy losses and contribute to make district heating systems much more energy efficient.

Keywords: Low temperatures, 4GDH, district heating, climate goals, energy efficiency, renewable energy, surplus heat, waste heat, heat pumps, digital, big data analytics, energy services, building balancing

Pietro Lubello is a PhD candidate in energy system modelling at the University of Florence, Italy, where he is working with simulation and optimization models for smart energy systems. He holds a BEng in Mechanical engineering and a MEng in Energy engineering.

Assessment of hydrogen based long-term electrical energy storage in residential energy systems

Pietro Lubello, University of Florence; Carlo Carcasci, University of Florence; Luigi Bottecchia, Eurac and TU Wien; Pietro Zambelli, Eurac

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Among the numerous envisioned applications for hydrogen in the decarbonization of the energy system, seasonal energy storage is usually regarded as one of the most likely options. Although long-term energy storage is usually considered at grid-scale level, given the increasing diffusion of distributed energy systems and the expected cost reduction in hydrogen related components, some companies are starting to offer residential systems, with PV modules and batteries, that rely on hydrogen for seasonal storage of electrical energy. Such hydrogen storage systems are generally composed by water electrolysers, hydrogen storage vessels and fuel cells. The aim of this work is to investigate such systems and their possible applications for different geographical conditions. Considered applications range from a mere way to increase total self-consumption, to a backup solution against major grid disservices or as an enabler for off grid systems based on variable renewable energy technologies. Each different option has been assessed from a technical point of view via MESS, an analytical programming tool for the analysis of local energy systems, and through an economic analysis. Results have identified the optimal dimensioning of system's components and have shown how, depending on future cost reductions, such systems might make economic sense for niche applications.

Keywords: hydrogen energy storage, PV, batteries, residential energy systems, smart energy systems, decarbonization

Andrew Lyden is a research associate in whole energy system modelling at the University of Edinburgh. His research is on modelling of energy systems including seasonal thermal storage with multiple energy sources as part of the INTEGRATE project.

Seasonal thermal energy storage in smart energy systems to provide flexibility services

Andrew Lyden, Daniel Friedrich, University of Edinburgh

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The transition from fossil fuels to non-dispatchable renewables poses significant challenges for the balancing of supply and demand. Seasonal thermal energy storage (STES) can provide flexibility services and are characterised by low cost per unit energy capacity and varying applicability to different geographical and geological locations. They have typically been installed to increase the utilisation of seasonally varying solar technologies, but they can also be integrated with multiple energy sources in smart applications such as utilisation of excess renewable generation; integration of waste heat; and provision of electrical network balancing. STES can enable synergies between energy sectors which, in accordance with the smart energy systems concept, can deliver optimal solutions for the overall energy system. They need to be modelled to understand performance and quantify potential benefits. Various energy system tools at the planning and detailed stage of design include STES, but they do not contain all the required functionality to capture key characteristics of STES and require exogenous inputs to represent the electricity network. Detailed physics tools can capture the complex heat transfer mechanisms of STES, while power system tools can model the connected transmission and distribution electricity networks. We are presenting the initial work on combining these to generate a whole energy system optimisation framework to design flexible smart thermal grids with STES.

Keywords: Seasonal thermal energy storage, smart energy systems, energy system modelling, co-simulation, waste heat, power-to-heat, electrification of heat

After a double European Master in Energy Engineering, **Erika Dal Monte** joined ENGIE as a deployment manager for NEMO, the digital platform of ENGIE specialized in the optimization of district energy systems. Erika is also part of ENGIE's international DHC team supporting projects all over the world.

Thermal Storage Integration in a Smart Thermal Grid

Erika Dal Monte, Instituto Superior Técnico ENGIE

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By 2050, nearly 8 out of 10 people are expected to live in cities with an increment in cold demand of 300%. One possible solution to reduce the effect of urban heat island, while reducing CO2 emissions are district energy systems such as district cooling network. In particular, new generations can operate at higher temperature (supply 8°C, return 15°C) allowing a more efficient integration of renewable decentralized energy sources and thermal storage systems. This study aims to validate the flexibility effort of a thermal storage application in an existing district cooling network. Operational conditions of cold-water storage and iced storage applications were simulated using two tools developed by ENGIE: 1) a cloud digital twin called NEMO which can simulate the entire network behavior hourly; 2) an AI algorithm for TES simulating different storage models and technologies. As secondary objective the study explored the feasibility of operating cooling networks at higher temperature while assuring a global network coefficient of performance (COP) above the contractual terms. The results demonstrated that, under the right conditions, thermal storage can play a valuable role as flexibility actor contributing to increase the global COP by 4% with annual savings between 30 and 40% in OPEX. Finally, it has been demonstrated that the utilization of higher temperature networks can increment the use of free cooling up to 50%, potentially reducing electricity consumption.

Keywords: Smart Grids, Thermal Storage, District Cooling, District Energy Systems, Thermal Grids, Smart Energy Systems, Smart Cities, Energy Transition, Energy Efficiency, Digital Twin, Machine Learning

Michael Reisenbichler 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 of TES on system level.

Methodology development for accelerated generation of thermal energy storage models for transient system simulations: Towards more efficient modeling and simulation of large-scale hot-water underground pit and tank TES

Michael Reisenbichler, AEE INTEC & Graz University of Technology; Keith O'Donovan, AEE INTEC; Carles Ribas Tugores, AEE INTEC; Wim van Helden, AEE INTEC; Franz Wotawa, Graz University of Technology

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Emerging Thermal Energy Storage (TES) technologies facilitate short-term and seasonal storage of volatile energy sources, provide peak load capabilities for power grids and thus enable coupling of the electricity and heating sectors. Therefore, they massively increase the flexibility and the share of renewable energies of our future energy systems. Due to the increasing complexity of these systems, multi-annual dynamic system simulations are necessary to effectively integrate new TES technologies and establish them on the market. Yet, the modeling of TES for system simulations is a complex and time-consuming process. Standardized procedures, guidelines or modeling toolboxes are missing. Hence, this project aims to develop methodologies for a more efficient development of new TES models in future. To achieve this, the modeling language Modelica is used. Acausal modeling with Modelica can significantly accelerate the modeling process compared to conventional causal modeling tools, such as TRNSYS. The basis for the deduction of general methodologies is the development of models for two emerging TES technologies: large-scale hot-water underground TES and thermochemical storages. To assess the plausibility, accuracy and usability of the models, they are validated with measurement data and benchmarked against established models. As a first step, a model for large-scale tank and pit TES has been developed and successfully validated against real measurement data of a Danish storage.

Keywords: Large-scale Thermal Energy Storage, Thermochemical Energy Storage, Dynamic System Simulation, Modelica, Model Development and Validation

Thomas Riegler studied civil engineering with a focus on construction process optimisation and management at the FH Joanneum Graz. Since 2019 he works at AEE INTEC in the field of thermal energy technologies with a focus on thermal energy storage systems.
Projects: “giga_TES, “MoreStore”, “Sol4City”.

Novel cover design with usable surface for large-scale pit thermal energy storages

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

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In order to ensure lasting functionality of large-scale thermal energy storages (TES) and particularly for pit thermal energy storages (PTES), innovative component designs and construction processes for PTES with volumes up to 2,000,000 m³ were developed within the Austrian flagship project “giga_TES”. As experience from existing projects has shown, the cover is one of the most expensive components of PTES. In addition, existing cover constructions resulted in high maintenance costs, early revisions, or complete cover replacement due to deficiencies. Therefore, the cover design is a crucial factor for a cost-efficient and functioning storage system.

Objectives: In addition to increased lifetime and low prices, also low thermal losses and usable cover surfaces, in order to increase the attractiveness and public acceptance of PTES, are important objectives for the development of new cover designs.

Methods: In order to achieve these objectives a detailed survey of the State-of-the-Art as well as of comparable constructions and an evaluation of possible cover design concepts has been conducted.

Results: A novel cover design with a submerged insulation layer and usable surface, called the “submerged cover”, was developed in the course of the project. So far, the design boundary conditions were defined and design drafts as well as construction and installation process methods were developed. A detailed cost estimation indicated strong potential for cost reduction of PTES.

Keywords: large-scale thermal energy storage, pit thermal energy storage, seasonal thermal energy storage, cover concept

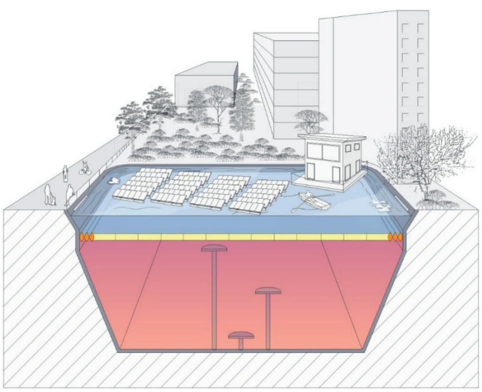

Figure 1

Aalborg CSP Product Manager & Senior Engineer, **Jesper Tange** is an experienced Master of Science in Mechanical Engineering from DTU Mechanical Engineer graduate with a profound experience within Pit Thermal Energy Storages (PTES). Throughout the past years Jesper has been a key person in the product management and project execution for PTES projects and has been a vital resource within the overall technology certification of the PTES with Lloyds. At Aalborg CSP Jesper is involved in the sales, product development and project execution of PTES solutions as well as supporting on thermal storage, energy systems and development in general.

Improving efficiency and scaling up Pit Thermal Energy Storages (PTES) with unique lid design

Jesper Tange, Morten Vang Bobach, Aalborg CSP

Jesper Tange (presenter) jta@aalborgcsp.com

There are substantial benefits of implementing a Pit Thermal Energy Storage (PTES) in an energy system. With its high flexibility and low cost, it enables a cost-efficient transition to a renewable and energy efficient future. Throughout the years, investments have been made to further develop, optimize and commercialise the PTES technology. The latest achievements in improving the insulated lid cover have matured the technology further, made it scalable and solved previous challenges.

Historically, PTES lids have caused severe technical issues and un-wanted thermal losses. This includes issues related to water accumulation inside the lid, water ponding on top of lid, air accumulation below the lid and thermal expansion. A new lid design has been developed with the aim of solving said issues. The new lid reduces the thermal loss and thereby improves the efficiency and reliability of PTES systems.
The new design from Aalborg CSP is based on two main principles. Firstly, the lid is designed as a diffusion-open top cover construction. The purpose of this is to address and solve issues related to water accumulation inside the lid due to water vapour diffusion through the liner. The diffusion-open construction allows the moisture entering the lid to diffuse out.

The second principle concerns the layout of the lid. The lid is divided into sections. The sectioning of the lid solves issues with water ponding, air accumulation and thermal expansion. Each section is designed with an inward fall towards the centre. This results in a very efficient handling of rainwater that flows towards the centre of each section. In the centre of each section, a pump well ensures removal of the water. This system makes it possible to drain the surface of the lid safely and automatically with no maintenance.

Moreover, the sectioning means that the PTES lid and the PTES technology in general are scalable. Much larger surface areas can be handled, as the number of sections and thus the number of pump wells will be increased.

Keywords: Pit Thermal Energy Storage, District Heating, Low-temperature Heat Storage, PTES cover

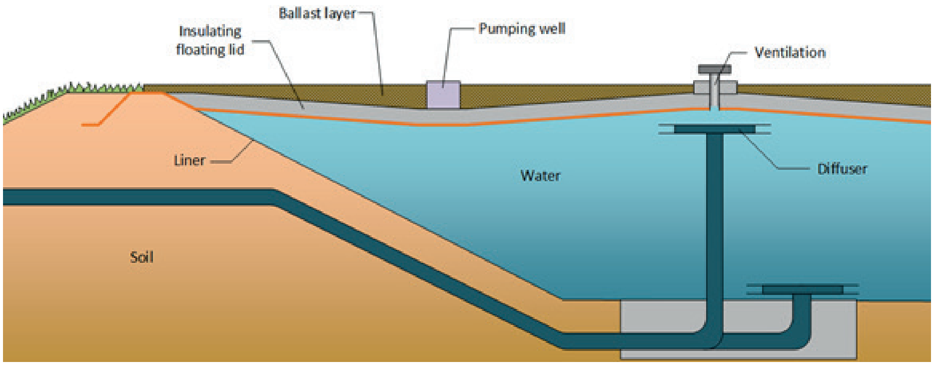

Figure 1: Principle drawing of Pit Thermal Energy Storage (PTES).

Mads R. Almassalkhi is Associate Professor at the University of Vermont, co-founder of startup Packetized Energy, and Chief Scientist at Pacific Northwest National Laboratory. His research interests focus on developing scalable algorithms that improve responsiveness and resilience of power systems.

Characterizing the reactive power capability of wind farm collector networks

Mads R. Almassalkhi, University of Vermont; Nawaf Nazir, Pacific Northwest National Laboratory; Ian Hiskens, University of Michigan

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A wind farm collector network can provide reactive power support at sub-transmission and transmission buses in order to support and improve voltage profiles. Previous works in literature characterize the reactive power capability of a wind farm by summing the individual generator ratings and do not take into account the constraints imposed by the wind farm's electric network, specifically, the voltage constraints. In this paper we determine the range of reactive power support that each generator within a wind farm can provide by constructing convex inner approximations of the non-convex set of admissible reactive power injections. The advantage of such a method is that it guarantees satisfaction of network constraints within the determined reactive power dispatch range. We present theoretical analysis that provides guarantees of this approach and also simulation results on wind farm networks that illustrate its effectiveness. Such an approach has the potential to improve the design and operation of wind farm collector networks, reducing the need for additional costly reactive power resources.

Keywords: Wind farm, reactive power, convex optimization, distributed control, distributed energy, network

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.

Flexibility enhancement using heat networks within large scale sector coupling studies

Marie-Alix Dupré la Tour, RTE & CIRED; Nicolas Lamaison, CEA; Virginie Dussartre, RTE

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The Paris Agreement has led to efforts to decarbonize all energy sectors, notably in Europe. They rely on 1) electrification and 2) decarbonization of other energy carriers (methane, hydrogen, heat). Besides decarbonization, the latter carriers can bring flexibility to an expanding power grid with growing renewables. District Heating (DH) has promising synergies with power via 1) conversion options using CHP or Power-to-Heat and 2) cheap and efficient storage features.

Yet, large-scale analysis of vector-coupling with DH is challenging due to the variety of generation systems in each DH network, unlike easily aggregable other energy vectors. We aim to analyze the flexibility gain offered by DH network to other energy grids considering the European energy system.

First, we mapped the flexibilities offered by DH. As for electrical ones, these flexibilities have different timeframes, from daily to seasonal. For example, a DH with a gas CHP plant and a heat pump (HP) could either start the CHP to satisfy the electrical demand or start the HP in times of electrical surplus. This could bring 1) daily flexibility with HP used mainly at daytime when electricity prices are low due to solar generation and 2) seasonal flexibility with electricity more used in summer than in winter. Second, we integrated representative current and prospective DH networks into a comprehensive European energy system model using the open-source Antares tool, to quantify the flexibility contributions.

Keywords: Flexibility, decarbonization, vector-coupling, power system, energy carriers

Søren Lyng Ebbehøj is a Chief Advisor in the CCS/PtX team at the Danish Energy Agency. He is a chemical engineer with a PhD in sustainable energy technologies and an avid interest in systems analysis, energy policies and the sustainable energy revolution.

Potential roles for power-to-x and CCUS technologies in Denmark's green transition

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Denmark is on a path towards reducing its GHG emissions by 70 pct. in 2030 compared to 1990 with electricity, district heating and gas sectors well under way towards carbon neutrality. As a next step, industry and passenger transportation have received some attention.
Reaching the 2050 targets of carbon neutrality however requires decisive efforts in industry, agriculture and heavy transportation. Direct electrification and utilization of Denmark's relatively large biogas potential is projected to cover parts of these sectors, leaving however a significant demand for additional emission reductions from other measures.
This study aims to discuss potential roles for new technologies such as power-to-x and carbon capture, storage and utilization in Denmark's green transition. In addition to this, various approaches to assessing the future scale and deployment of these technologies are discussed.
The study compares deployment potentials for new technologies and expected demands from hard-to-abate sectors. This comparison aims to address a series of questions relating to the deployment of new technologies in a Danish context. These include the future role of solid biomass for energy purposes, the balance between CCS and CCU, and to which extent carbon based e-fuels (as opposed to hydrogen or ammonia) could play a role in the efforts to reach the national long-term climate targets.

Keywords: Power-to-X, Carbon capture and utilization, Carbon neutrality

Philip Fosbøl is a leading EU expert on CCS. He is currently leading 6 larger Danish and EU funded research projects. He is currently supervising 7 PhD students and he has published more than 60 papers. He holds a position as board member of the geological Surveys of Denmark.

Potential for CCS and CCUS electrification towards reducing impact of climate change

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CCS (Carbon Capture and Storage) and CCUS (Carbon Capture, Utilization and Storage) are technologies which removes CO2 from large-scale industry or directly from the air. The focus is to store the CO2 underground or convert it to valuable products. CO2 capture is a technology know from the 1920th. During the increasing oil & gas production of the 1970's it was sized for removal of CO2 on a million ton annual scale. The technology we see applied today derives back from the original ideas and there are many ways to use electricity for reduction of the energy consumption and cost, but also for a more flexible integration into an electrified society. The scale needed for a real climate impact calls for large removal of CO2 but how much do we really need to take CCS and CCUS into account? There is a substantial need. If we decide to electrify the technologies and incorporate a significant amount of CO2 utilization, there must be an infrastructure capable of delivering a significant amount of power. This is true for Denmark, but to Europe as a whole. The presentation outlines existing technologies and present the most recent ongoing research on electrifying CCUS. The electrification potential is discussed in a context of a multi scale CO2 infrastructure producing significant amount of synthetic fuel and product from CO2.

Keywords: CCS, CCUS, CO2 capture, CO2 utilization, CO2 infrastructure, electrification

Oddgeir Gudmundsson holds a PhD degree from University of Iceland. He has worked with Danfoss for 9 years, with a global focus on the district energy field.

The role of hydrogen in the future heat supply system

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

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Hydrogen advocates commonly mention it as the future proof energy carrier and actively communicated that a transition from natural gas to hydrogen can be achieved with gradually increasing the hydrogen concentration in the gas supply. The long-term source of the hydrogen is said to be green, in the short term it would be produced from natural gas, but in a decarbonized way, giving it the code name blue hydrogen. While blue hydrogen and eventually green hydrogen, produced using green electricity in an electrolysis process, has undoubtably a role to play in the future energy system it is important to see it in relation to the energy demand it is supposed to fulfill and the alternative energy carriers, such as electricity and hot water. By taking a holistic view on the future green energy system it becomes clear that while hydrogen certainly has important properties as an energy carrier it does have limitations that restrict its future role to specific areas of the energy system, which does not include residential heating. In this paper the efficiency of a green hydrogen-based heat supply will be compared to alternative heat supply systems, individual natural gas boiler, electric radiators, residential heat pumps and electrified district heating system. The analysis will further investigate the efficiency and greenhouse gas impact of blue hydrogen-based heat supply, from the mining of the raw natural gas to the end-user demands against the above alternative heat supply systems.

Keywords: Heating, district heating, heat pumps, hydrogen, efficiency, greenhouse gases.

Anders Bavnhøj Hansen is chief engineer at Energinet. Fields of expertise are strategic planning of integrated energy systems, energy system analysis and R&D strategy development.

System scenarios towards climate neutrality by use of smart Energy systems solutions

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The political ambition in Denmark is to realise a climate neutral society by 2050. Realising a climate neutral society implicates negative emissions from the energy system, as some emissions outside the energy supply are very hard to totally avoid. Energy system scenarios towards this climate neutral target is in this study analysed and presented. A scenario with negative emissions of 10 million ton CO2 from the energy system is used as a case.

To realise such ambitious targets a comprehensive integration of energy vectors is found to be essential (Smart Energy System solutions). This includes integration of energy vectors such as power, hydrogen, methane, ammonia, heat and CO2. A seamless integration and operation of these energy vectors is required to realise a cost-efficient and resilient energy supply in the carbon neutral society.
Optimised use of the power grid by use of flexibility from the linked system is analysed. A hydrogen grid is found to be an essential part of the energy system and examples of potential system structures are illustrated. To realise negative emission from the energy system, solutions with capture of CO2 from biobased sources and waste (BECCS) and direct air capture (DAC) are analysed.

As Denmark is sited in an area with a significant surplus of renewables from offshore wind, the international role of these resources is a part of the scenarios study. Finally, essential R&D paving the way for the transition is discussed in the presented study.

Keywords: Smart Energy Systems, Energy system scenarios, climate neutrality

David Huckebrink recently obtained his master's degree in engineering at the Ruhr-University Bochum. Currently, he is modelling energy systems with the goal of a fast and feasible energy transition.

Coupling and comparison of hydrogen technologies with heat-pumps to decarbonise the residential heating sector

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Reaching the global climate targets implies the decarbonisation and solving adhered challenges for each energy sector locally. Extrapolating trends of electrification, the residential and the mobility sectors are being coupled to the power sector, sharply increasing flexibility requirements to balance supply and demand. However, the crucial factor is the mode of appliance use, because optimised operation of these integrated technologies could increase system flexibility and efficiency.

For instance, heat pumps or waste heat of hydrogen appliances can be used and stored in thermal energy storages or by temporarily increasing room temperature. Moreover, waste heat of hydrogen appliances could be used by heat-pumps, enhancing efficiency in winter, when heat demand coincides with hydrogen usage for power supply. However, these means of heat provision typically require costly building efficiency upgrades. Alternatively, hydrogen can be combusted in order to provide high temperature heat, using already existing infrastructure and saving on the insulation. This might be useful for the transition phase towards a renovated building stock.

In this work, several means for low carbon heat provision are analysed on a municipal level. Based on real data, a digital twin is developed with the energy systems model backbone. The resulting differences in system composition and system cost will be shown.

Keywords: Residential Heat, Power-to-Heat, Sector Coupling, Seasonal energy storage, Hydrogen

Andrei David Korberg is an Assistant Professor at the Department of Planning at Aalborg University. He recently completed his PhD fellowship, where he focused on the role of renewable fuels in future energy systems. He works with energy system analysis and techno-economic assessments.

Supply chain effects of the extreme hydrogen society

Andrei David Korberg, Brian Vad Mathiesen, Henrik Lund, Jakob Zinck Thellufsen, Miguel Chang, Susana Paardekooper, Aalborg University

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Hydrogen is often suggested as a natural gas substitute for supplying heat, electricity, industrial demands, or replacing oil products in transport. This paper analyses the potential of hydrogen in all four energy sectors in a 100% renewable energy system for Europe in 2050 in hour-by-hour energy system analysis. Our results show that, in general, the viability of hydrogen is limited by three factors: energy efficiency, resources allocation and infrastructure costs. Using hydrogen for heating is detrimental to all three factors, while hydrogen for electricity production can only be beneficial in limited quantities to restrict biomass consumption. The transport sector results show that hydrogen is an expensive alternative to liquid renewable fuels due to the high infrastructure and storage costs. On the other hand, the industry may benefit from hydrogen, where due to its specific demands, this can support previously carbon-intensive processes, a measure that can also limit biomass consumption. Seen in a systems perspective, hydrogen must be used with caution and should only supplement more efficient technologies as district heating and electrification and used as resource for producing electrofuels in transport.

Keywords: hydrogen society, energy efficiency, smart energy systems, fuel storage, infrastructure, 100% renewable energy systems

The research field of **Mathias Müller** is grid integration of decentral flexibility options (electric vehicles, batteries, heatpumps). His focus is on charge management of electric vehicles. He is working since more than five years at the FfE and is responsible for the grid simulation model GridSim.

Future grid load with bidirectional electric vehicles

Mathias Müller, Yannic Schulze, Janis Reinhard, Adrian Ostermann, Forschungsstelle für Energiewirtschaft e.V. (FfE)

Mathias Müller (presenter) mmueller@ffe.de

Bidirectional charging of electric vehicles (EV), often called Vehicle2Grid (V2G), has the possibility to foster the energy transition. The growing number and rising battery capacity of EV enables different ways of integrating them into electricity grids. In the project "Bidirectional Charging Management" different use cases, like optimizing PV self-consumption, price optimization or providing grid services are defined, evaluated and tested in a field test with 50 EV. In this paper the scope is on the resulting grid loads due to the different V2G use cases. Therefore, an energy system model with integrated load flow calculation to simulate future scenarios of low voltage grids is expanded with an optimization algorithm to provide the V2G use cases. To evaluate the grid load more than 1.000 real low voltage grids were combined with future scenarios regarding photovoltaic systems, electric heating and mobility. The local grid use case is in addition to the other use cases and enables the distribution grid operator (DSO) to set power consumption limits to avoid grid overloading (§ 14 a, German EnWG).

The main conclusions are the resulting grid load and potential need of grid expansion caused by the future scenarios. Besides this also the resulting simultaneous grid load per EV or grid connection point is analysed to give advice for the planning principles of DSOs. For the grid use case also the number of interventions by the DSO and the effect of these are analysed.

Keywords: V2G, Bidirectional Charging, electric vehicle, grid integration, distribution grid, smart grid, flexibility, electrification, simulation, tools, energy system analysis

Thomas Natiesta has a mechanical engineering background and has specialised in renewable energy systems. His main interest lies in the intelligent integration of heat pumps into district heating networks.

Testbed to evaluate digital solutions in integrated district heating and electrical grids: First results

Benedikt Leitner, Edmund Widl, Aurelien Bres, Andreas Sporr, Stefan Hauer, Klemens, Marx, Ralf-Roman Schmidt, AIT Austrian Institute of Technology GmbH

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The integrated operation of electrical and thermal networks is an important aspect of sector coupling in local energy networks. The evaluation and development of automation and control solutions as well as ICT in such smart energy systems is complex and involves considerable time and cost expenditure. Performing system-level tests on these components currently requires the implementation of pilot or demo projects. The considerable time and costs involved prevent a rapid market introduction. Furthermore, the transferability and comparability of results from different demo projects is difficult due to the strongly varying regional conditions and requirements (existing network topologies or buildings, availability of energy sources, load and generation profiles, etc.).

This work presents first results for the implementation of a testbed for digital solutions in integrated district heating and electrical networks at AIT Austrian Institute of Technology GmbH. The combination of digital and physical coupling means to integrate existing laboratory infrastructures (smart grid laboratory) and testbeds (district heating substation, heat pump, etc.) in combination with the targeted use of simulation models (district heating network, building simulation, etc.) represents a promising alternative to expensive pilot project and could lead to standardized and holistic tests for cross-domain applications (especially for automation and ICT solutions) on a network-level.

Keywords: sector coupling, testbed, hardware-in-the-loop, controller-in-the-loop, smart district heating, smart grid, control

Henrik Schwaeppe is conducting research and pursuing his doctorate at RWTH Aachen University. Engineer by trade, his work is often related to energy economics and optimisation problems. As part of the research project PlaMES, he investigates sector-integrated energy system designs of the future.

Analysing systemic advantages of district heating in an integrated transmission and generation expansion planning model

Henrik Schwaeppe, Paula Baquero, Klemens Schumann, Lukas Hein, Luis Böttcher, RWTH Aachen University.

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Promising climate-gas emission reduction potentials are associated with the coupling of the energy sectors of heat and electricity. E.g. heat pumps are powered electrically with a heat output that is a multiple of the electrical energy used. But regardless of their high efficiency, the expected roll-out of heat pumps puts stress on the electric energy system. Furthermore, as the energy system of the future will dominantly be fueled by fluctuating renewable energy, one has to consider storage opportunities to provide clean and comfortable heating even in cold seasons. Compared to local heating and besides the high initial investment cost, district-heating offers several advantages, such as cheap thermal storage, the possibility to install multiple heat generation options and generally the possibility to scale, which reduces the cost of installation and maintenance. To determine potential systemic benefits and to quantify cost reduction potentials of district heating, we derive heat and electric demand bottom-up from a spatial database, run a sector-integrated transmission and generation expansion planning model that outputs technology expansion decisions as well as hourly schedules with special consideration of district heating expansion and analyse resulting energy system designs through a sensitivity analysis on an exemplary test case. Successful full-year-runs with 120 electric nodes and 197 heating areas have already been applied and may be enhanced for this study.

Keywords: generation expansion planning, transmission expansion planning, district heating, energy system designs

Lu Shen is currently working toward the PhD degree in electrical engineering with Southeast University, China. Her research interests include modeling, simulation, and optimization algorithm of integrated energy systems.

Multi-energy cluster partition with CHPs for distributed optimization and control of the integrated energy system

Lu Shen, Xiaobo Dou, Southeast University.

Lu Shen (presenter) lushen_2020@outlook.com

The integrated energy system consists of the active distribution system and distinct heating system, which has great potential for flexibility. In northern China, the heat for a large heating network comes from many combined heat and power (CHP) plants in different locations. Analyzing the complex interactions in such integrated system is not straightforward. This work proposes a partition method of multi-energy clusters with CHPs, as a rapid development of cloud-edge computation technology provides support for distributed management. In terms of the structural property, the heat loss along the pipeline is calculated, and the modular index is applied to quantify the connection strength between the different two nodes. For the functional property, a supply-demand balance index is designed to compare the CHP heat production and consumption in a heating cluster. We utilize the Louvain community detection algorithm to partition the two energy systems into several initial single energy clusters, respectively. The electrothermal coupling degree is further investigated to match and combine the initial clusters by evaluating the cogeneration and actual consumption. The effectiveness of the proposed indexes is verified on a simulation system consisting of a 69-bus distribution network and an 83-bus heating network with 8 CHPs. The multi-energy cluster partition can reduce the power loss across clusters and achieve a 40% computing time saving compared to the centralized method.

Keywords: integrated electrical and heating system, multi-energy clusters, combined heat and power, structural and functional indexes, Louvain community detection algorithm

Aalborg CSP Senior Sales and R&D Manager, **Hammam Soliman** is an experienced electrical and energy engineer holding more than 8 years of experience within the R&D field. During the years, he has published several scientific papers and high-level journals that contributes to both the academic and the industry fields. Hammam earned his Master degree within the performance of wind energy turbines and performance improvements against faulty conditions. He completed his Ph.D. from the Energy Technology department within the reliability of power electronic converters and components by applying advanced algorithms based on artificial intelligence.

Power-to-X / Electricity-to-Hydrogen – CAPEX & OPEX Vs. Integrated Production

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This abstract aims at exploring the contribution of high-temperature thermal storage to the optimization of hydrogen production as part of the Power-to-X business.

During the past decades, the primary concern and focus has been on the generation of electricity, while the current focus has been moved towards storage and utilization of the excess generated electricity. In this respect, substantial focus has been put on the Power-to-X (PtX) technology. The present understanding is that excess electricity must be converted directly into hydrogen by installing electrolysis systems large enough to manage the peak power from the grid, thus offering grid balancing services. There is, however, an alternative where the balancing of the grid is done through installation of large high-temperature energy storages. Such systems are also considered in the retrofitting of coal-fired power plants. Conversion by integrating high-temperature energy storages would repurpose most of a coal plant's assets. Moreover, a large part of the energy produced can be converted into district heating/cooling through the integration of a Pit Thermal Energy Storage (PTES). A major question raised within this abstract is, if the Hydrogen price vs. capex can be decreased through the integration of a thermal battery and sector coupling enabling multiple revenue streams, with cheaper Hydrogen as a result.

In this abstract, a conceptual design of an integrated system that combines the production of hydrogen and energy storage in thermal batteries is presented. The design is based on the electrification principle of utilizing excess electricity generated from wind turbines and storing it in high temperature molten-salt storages. In such a configuration, the integration of storage will provide flexibility in terms of purchasing electricity at low prices. This makes it possible to optimize the size of the electrolysis through securing a stable supply of power. This to such an extent that the electrolyser will be able to operate close to its design point 24/7 enabling lower price of Hydrogen or better return of investment (ROI) of the plant.

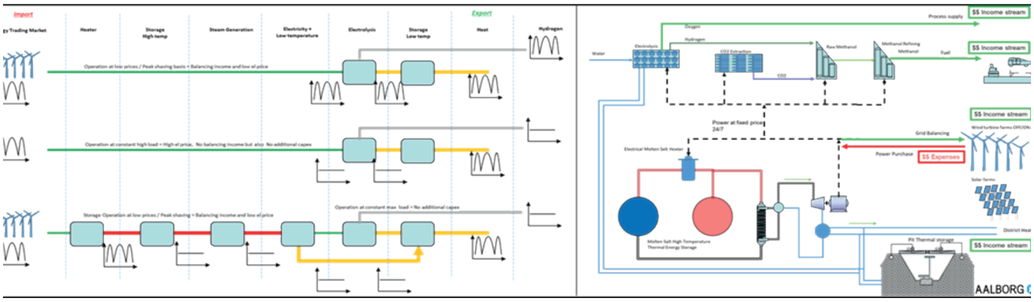

Figure 1: Comparative Illustration of the PtX/Hydrogen Configuration with respect to the import of electricity.

In Fig.1, three different hydrogen production scenarios are illustrated. The given scenarios are comparable from the import/export of electricity/hydrogen point of view, respectively.

Scenario	Philosophy Description	CAPEX Vs. Availability	OPEX Vs. Revenue
Scenario A	Importing electricity during low prices, fluctuating production of Hydrogen	Optimized Electrolysis CAPEX + high-capacity factor	Controlled OPEX + High revenue stream
Scenario B	Importing electricity all the time regardless the prices, constant production of Hydrogen	High Electrolysis CAPEX + low-capacity factor	High OPEX + limited revenue stream
Scenario C	Importing electricity during low prices + Storage backup, constant production of Hydrogen	Optimized Electrolysis CAPEX + high-capacity factor	Controlled OPEX + high revenue stream

Investing in the integration of a high-temperature thermal storage on the supply side as well as a PTES on the off-take side within the configuration of Pt-Hydrogen, potentially provides an improved tecno-economical case. However, to obtain any conclusion of the comparison of Scenario A, B and C, a business case study is recommended.

Keywords: Sector Coupling, PtX, e-fuel, Hydrogen, Green Transition, Thermal Energy Storage

Sara Ben Amer holds a PhD in Energy Planning from DTU. Currently she is employed as a Postdoc at DTU researching digitalisation of energy systems, smart sustainable cities and the application of energy models for planning urban energy systems.

How successful is municipal energy planning in Denmark - quantifying the impact

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The majority of global CO2 emissions can be traced back to urban areas. While national and global commitments to GHG emission reduction are crucial, in the last decade cities and towns have been the leaders of the energy transition. Many municipalities have proposed ambitious goals and plans, but they still encounter barriers within the planning and implementation process. As part of the FlexSUS project, this study departs from a qualitative analysis of barriers to successful energy transition perceived by municipalities in Denmark and Sweden and a review of supportive regulatory framework conditions. That analysis provided a number of policy recommendations on the adjustment of regional and local regulatory settings for an efficient energy planning and policy framework. What remains unclear in the literature is the impact of municipal energy planning on the actual implementation of RES and energy savings - and resulting CO2 emission reduction.

The aim of this paper is to assess how ”average” municipalities compare to energy planning leaders concerning CO2 emissions and deployment of RES. By comparing the cities on key performance indicators, we attempt to show whether there are differences between ”progressive” and ”standard” cities. Our expected results will depict the quantitative value and efficiency of energy planning initiatives in ”progressive” Danish municipalities. This knowledge can be used to improve the strategic energy planning efforts in Denmark and elsewhere.

Keywords: strategic energy planning, smart energy systems, municipalities, policy adoption evaluation

Prof. **Dagnija Blumberga** is internationally recognized expert in various topics related to energy production, RES, climate change, environment technology. He has experience in more than 10 international projects and more than 30 local projects as researcher, expert, and project leader.

Smart Heat Tariffs in transition to free market

Dagnija Blumberga, Ieva Pakere, Krista Laktuka

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Innovative pricing mechanisms are one of the key aspects in order to motivate both heat suppliers and consumers to move toward more sustainable energy systems. Therefore, also regulation regimes should be changed in order to stimulate changes in the energy sector. The authors evaluate the possibility to introduce smart heat tariffs as a transition pathway toward an unregulated district heating market.
The district heating (DH) tariffs depend on a large number of factors which include fuel prices, operational parameters, taxes, investments, and other criteria. An analysis of the DH tariffs has been implemented to find solutions to motivate DH enterprises towards energy efficiency and climate neutrality. An analysis of the district heating tariffs has been implemented to find solutions to motivate district heating enterprises towards energy efficiency and climate neutrality. The innovative methodology for analysis has been developed and consists from two parts: multicriteria analysis and benchmarking methodology. The results of analysis are based on decision making assessment approach by selection of miscellaneous criteria and evaluation of them from five significant aspects: engineering, environmental, climate, economical and socioeconomical. Different district heating regulation mechanisms have been tested in order to find the balance in smart energy systems between the DH operators and heat consumers.

Keywords: district heating regulation, smart energy systems, demand side management, energy efficiency

Claudia Mădălina Dumitru graduated the Faculty of Power Engineering, University Politehnica of Bucharest in 2019 and is currently working as Research Assistant in the WEDISTRICT project.

Optimizing the development process of a hybrid energy supply system based on renewable sources using the LEAN methodology

Claudia Mădălina Dumitru, Roxana Pătrașcu, Mihai Rareș Sandu, Constantin Ionescu, University Politehnica of Bucharest

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An innovative research project for the development and implementation of a thermal and electrical energy production system, using exclusively renewable energy sources, requires a dynamic way to reduce various losses, the most efficient use of human resources, financial and material resources while maintaining the schedule of the execution plan. The LEAN methodology allows the optimization of the project management by achieving all the proposed objectives. This methodology allows a strategic management divided in four phases: planning, procurement, design and construction, which, if combined and applied correctly, should reduce every form of waste in any project. By applying this method, some advantages are brought to light. First comes the ability of reducing wasteful activities, which leads the team to be more focused on activities that are valuable. Another advantage is brought to the efficiency and productivity, both of which are increased. This paper presents the last stage of the methodology practically applied in the European project Horizon 2020 (no. 857801) “Smart and local reneWable Energy DISTRICT heating and cooling solutions for sustainable living” - WEDISTRICT for the development and implementation of a hybrid energy supply system based on renewable sources implemented at the demonstrator in Bucharest.

Keywords: management, planning, resources, hybrid system implementation, thermal energy production and distribution, renewable energy

Pei Huang is an assistant professor in Energy Technology at Dalarna University. His research includes multidisciplinary topics across subjects of energy, buildings, and green transportation.

5th generation district heating and cooling implementation potential in urban areas with existing district heating systems

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The 5th Generation District Heating and Cooling (5GDHC) network has great advantages in integration of low temperature resource, bi-directional operation, decentralized energy flows, and possible energy sharing. However, there are research gaps, related to this technology: the lack of a simulation platform for rapid prototyping in different regions, the unknown technical and economic performance in various conditions, and the lack of feasibility study for early opportunities and potential barriers. One of the way to develop the idea and concept of 5GDHC is to identify potential agents, including residential buildings, office buildings, shopping malls, data centers, electric transformers, etc. in 5GDHC in each target context. Perspectives for 5GDHC will be evaluated for the conditions in the Baltic-Nordic region. Country specific conditions, such as heating tariffs, existing business models, regulation mechanisms, stakeholders, existing infrastructure, district heating market and others will be evaluated for Latvia, Estonia, Lithuania and Sweden. It should be noted that new urban areas in the Baltic states are being actively built up with low-energy buildings, therefore 5GDHS can be integrated to supply heat to these areas. Based on preliminary evaluation possible potential for 5GDHC network implementation in the Baltic states will be presented.

Keywords: 5GDHC, urban waste heat, excess heat, heat pumps, data centers, district cooling

Tore Friis Gad Kjeld is an energy planning specialist, focusing on the integration of new production technologies into the DH system. His expertise is in the fields of electrification, digitalization, heat pumps and optimization of energy systems.

District Heating in Copenhagen – challenges and perspectives

Nick Bjørn Andersen, HOFOR

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Our Challenges: HOFOR District Heating is striving to tackle some major challenges in the next 5 to 10 years: the regulatory framework is under change, opening for the competition from individual distributed heat pumps - and there is a growing need for smart interaction with the district heating customers. Moreover, we are aiming at 100% CO2-neutral district heating by 2025.

It is important for HOFOR to satisfy the expectations of customers, not only regarding the district heating price, but also with respect to CO2-neutrality, operational easiness and relevant digital interaction with substations and between the customer and HOFOR. We expect a growing number of individual heat production plants in existing district heating areas as for example heat pumps. In some cases the 'customer' prefer to us district heating in peak load hours only, which is not going well in hand with our existing tariff structure, where only 20% is paid for per kW capacity.

Another challenge is the performance of the consumers' substations, impacting the network losses and the efficiency of production plants.

Our perspectives: We are underway introducing various means of improving the services to the customers and improving the economy of district heating operation e.g. reduction of peak load, digital monitoring and control of the substations' performance aiming at reduction of network temperatures and smart piping renovation. Along with that, we are investigating relevant smart energy options.

Keywords: District Heating, economic efficiency, customer interaction, performance of substations, smart energy

Britta Kleinertz is a researcher and energy consultant working in the fields of industrial energy supply optimization as well as municipal heat supply concepts

Heat Transformation Munich – Analysis and strategy definition for a systemic cost optimal heat supply transformation

Britta Kleinertz, FfE

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Munich plans to achieve climate neutrality by 2035. This creates challenges for the city, particularly in establishing a legal framework capable of enabling the transformation, and for the utility, which must undertake infrastructural adjustments.
With the aim of transforming the heating sector as cost-efficiently as possible, relevant heat transformation solutions are prioritized based on their potential limitations within individual districts and their respective CO2-mitigation costs. Here not only the technical potential is included, but also practical limitations in potential exploitation per year. While CO2-mitigation costs are determined for district heating by a marginal approach, decentralized heating systems are regarded with their full costs. Here a regionalized and consumer type specific analysis is implemented. The main conclusions include:

- In many cases, the technical potential is not the limiting factor for transformation, but the possible transformation rate of components.
- CO2-mitigation costs help to prioritize solutions for heat supply strategies. Here it is essential to differentiate regionally, by consumer type and by stakeholder perspective regarding the inclusion of cost components.
- As refurbishment rates are, and will remain, lower than the modernizations of heating units, bridge technologies are essential to reach cost-efficient heat supply. Final quantitative results will be publicly available by May and then embedded into the paper.

Keywords: Heat supply, decarbonisation, transformation strategy, district heating

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 and energy efficiency. Saija Toivonen D.Sc. (Tech.) is an assistant professor in Real Estate Economics at the Aalto University.

Understanding the profitability of the energy (efficiency) investments – things to consider before putting billions into game

Ari Laitala, Sykli Environmental School of Finland; Saija Toivonen, Aalto University

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Investment analysis is never an easy task. Not even in those situations where the calculations as such may be somewhat straightforward. The profitability of the investment ultimately depends on the events and coincidences of the future and cannot be known for sure beforehand. Nevertheless, a sophisticated investment analysis should recognize and describe different futures and be able to quantify them for calculation purposes.

Many experiences and observations suggest that investment analysis tends to be simplistic and may focus only on single figures. For example, experience from the Finnish energy investment landscape shows that even relatively large investments could be considered based on payback time calculation alone. It is unclear why the approaches and procedures seem to be so simple.

The ongoing energy transition suggests that the existing investment landscape is very complicated and more thorough analyses would be useful rational. A deep exploitation of both quantitative and qualitative approaches is supposed to be useful when considering hundreds of billions of energy-related investments in the Europe alone in the coming years. A possible enhancement for investment analysis is applying methods from the field of real estate valuation. Standardized valuation methods have been in use there for decades. Quantitative conclusions are based on deep qualitative considerations and highly developed procedures could have great relevancy in the energy sector as well.

Keywords: energy, investment analysis, valuation standards, foresight methodology, alternative futures, income approach

Hannah Mareike Marczinkowski has written her PhD on the work on 'Modelling Renewable Energy Islands', where she highlights the contributions of islands to modelling and to energy transitions globally. Coming from a German island, Hannah works with sustainable energy planning and SES across different contexts and islands.

Modelling renewable energy islands and their role in energy transitions

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This work contemplates and defines the role of modelling renewable energy, especially on islands, in the transition to sustainable and highly renewable energy systems. It addresses the Paris Agreement through the uptake of renewable energy technologies and how the 80,000 islands globally may contribute to developing those both on islands and elsewhere. With a particular focus on three case studies – Samsø, Orkney and Madeira – the work highlights general perspectives of islands, the potentials and limitations on islands, and the understanding we can gain from them. Thereby, the thesis contributes to energy planning in three ways. First, the concepts of smart energy systems and islands are elaborated and combined. Second, the theories of transition and governance are illustrated through island perspective. And third, the methods of energy system analysis and case studies are applied and contemplated through a review of publications on the topic of modelling with islands. The work presented critically reflects on the modelling work done with islands and, despite being located on the edge, how the work benefits both energy planners and islanders through cutting-edge contributions. The coordination of the research done with islands and the acknowledgement they deserve will benefit energy planning, also in future research around marine and artificial energy island developments, by supporting the transition towards 100% renewable energy share and the fight against climate change.

Keywords: Renewable energy, energy islands, energy transitions, smart energy system, sustainable energy planning

David Maya-Drysdale researches about the energy transition of European countries and cities. With particular focus on the planning towards energy transition visions. Planning can involve energy scenarios, city plans, business models, policy, and intermediation between actors.

Achieving carbon neutrality in cities: Lessons from a leader

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This article evaluates how intermediaries can support and facilitate the energy system transition in municipal regions. Intermediaries have the capacity to mediate between numerous stakeholders and guide the transition process. This article argues that the energy transition requires intermediaries to possess certain characteristics and operate in a certain way, in line with the concept of a decarbonized energy system. The involvement and influence of human and non-human actors in the process of mediation is important to understand. Thus, the analysis studies the role of human and non-human actors involved in the mediation process of ProjectZero, an experienced intermediary in Sonderborg, Denmark. Actor Network Theory provides the basis for the analytical framework applied in the study. Although ProjectZero is an experienced and well-functioning intermediary, the results show that key non-human actors, for example biomass, are not participating in actor engagements and mediations to the extent necessary in the energy transition. This has implications for how stakeholders engage and how decisions are made. This article concludes with suggestions for improving the participation of intermediaries in the energy transition.

Keywords: Urban planning, Intermediary, Climate Change, Renewable Energy, City

Mateo Pozzi is the CEO of Optit, digital innovation company that develops Decision Support Systems based on Operations Research and Data Science, and Vice-Chair of DHC+, innovation platform of Euro Heat & Power. He will present with Alessandro Capretti, Head of District Heating Network Planning and Design at A2A.

Planning large district heating network developments based on Waste Heat Recovery

Matteo Pozzi, Optit srl; Alessandro Capretti, A2A Calore & Servizi srl; Andrea Bettinelli, Optit srl; Stefano Morgione, Optit srl; Giacomo Mandrioli, Optit srl; Diego Costa, A2A Calore & Servizi srl

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A2A Calore & Servizi (ACS) owns and manages several District Heating (DH) systems in the North of Italy. Considering the EU climate action plan, the opportunity to recover waste heat from the Cassano d'Adda power station provides unique opportunities for DH development in the metropolitan area of Milan, where a huge amount of heat (more than 1TWh) can be recovered and conveyed through a transport backbone of more than 30km, using storage units to further increase peak capacity.
The core challenge for ACS is the pre-feasibility assessment of the system: having virtually limitless opportunities to design the distribution network, achieving a reasonable return on the investment by targeting the most promising customers/areas, while also allowing capacity for further developments is a key success factor.
The advanced digital solution developed by Optit was used to find the most appropriate layout, dimensioning and ensure viable future operations. Joining the industrial experience and vision of ACS with innovative digital tools required the definition of an original, agile methodology to work through potentially endless scenarios, converging towards significant targets within challenging timeframes. The project, methods and key evaluation criteria will be reviewed, setting a benchmark for large developments feasibility analyses, that will be increasingly relevant in the future, as DH becomes a strategic asset for achieving the challenging EU decarbonization targets.

Keywords: district heating network, waste heat recovery, climate action, optimisation, digitalization, decarbonization

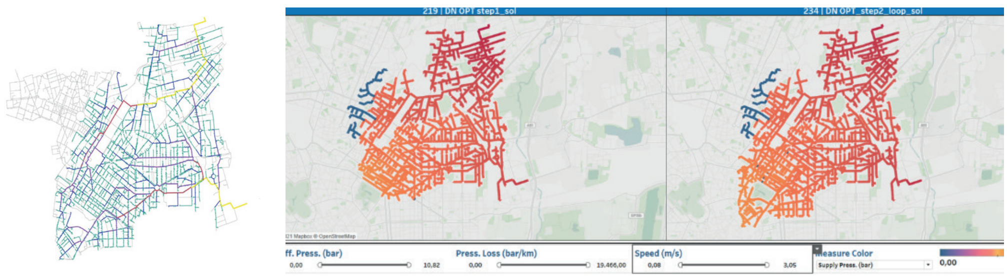

Figure 1: Scenario analysis of the potential distribution network developments

Alexandra Purkus is a Senior Researcher at the Hamburg Institut and holds a PhD in economics. Her research focuses on renewable energy marketing strategies and policy design as well as the role of energy tracking systems. Previously, she has worked as a Postdoc in environmental and energy research.

Guarantees of Origin for green district heating: An analysis of legal framework conditions and system design options

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In electricity markets, Guarantees of Origin (GOs) are an established system for tracking energy attributes from production to consumption. The recast Renewable Energy Directive (RED II) has extended the scope of GOs to gas and heating and cooling from renewable energy sources. This could open new perspectives for marketing green district heating and cooling (DHC) products – green price premiums could improve the business case of integrating renewables into DHC grids. However, GO systems need to be adapted to the technical, organisational and institutional framework of DHC markets. Also, there are uncertainties about the legal framework for marketing green DHC products backed by GOs.

This contribution presents the results of a legal framework analysis, focusing on European energy law and German regulations as a case study. Moreover, we analyse design options for GO systems for heating and cooling. While boundary conditions are set by the RED II and the European Norm EN 16325 which is currently under revision, various questions remain, e.g. regarding the transferability of GOs across non-interconnected grids, the handling of grid and storage losses, or the definition of disclosure rules. We assess options from an institutional economics perspective, taking into account transaction cost implications and interactions between GOs and the sectoral policy mix. Also, insights from workshops with heating sector actors contribute to the development of recommendations.

Keywords: Guarantees of Origin, district heating, district cooling, green energy marketing, renewable energy sources, waste heat sources, energy law, institutional economics

Daniel Møller Sneum is a 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.

Discounting assumptions in district energy

Daniel Møller Sneum, DTU Management; Emilie Rosenlund Soysal, Potsdam Institute for Climate Impact Research; Frikk Nesje, University of Copenhagen; Mark C. Freeman, University of York Management School

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District energy systems are evaluated according to private or social economic framework conditions. One of these is the discount rate, which is applied to represent the time value of money. But how is it set and what impacts can it have on district energy projects? To answer this, we review how discounting is applied in international guidelines, we unravel the Danish guidelines for discounting and we quantitively analyse the impact of discounting on a specific Danish geothermal project.

The review shows the Danish social discount rate of 4% to be in the mid-field among rates applied across countries surveyed. Further, the study of underlying assumptions for the Danish guidelines on socio-economic evaluation of energy projects shows a variety of approaches and assumptions regarding discounting. Finally, the case study reveals robustness regarding variations in the discount rate.
Among the conclusions are that the Danish discount rate overall may be reasonably set, but with some room for improvement. Regarding the Danish guidelines, there is limited consistency in the approach taken across different steps of the analyses leading up to the guideline's numbers. This problem may apply in other countries with similar approaches to such analyses. It may be relevant to take steps in the direction of more uniformity in developing the preconditions for the Danish guidelines on socio-economic evaluation of energy projects.

This study is part of the HEAT4.0 project.

Keywords: district heating, district energy, discounting, economics, financing, geothermal

Vittoria Battaglia is a PhD candidate at University of Neaples 'Parthenope' (Italy). She is an environmental engineer and her research work is currently focused on sustainable energy systems modeling and analysis.

The role of local energy planning in the achievements of regional and national sustainability targets: an Italian case study

Vittoria Battaglia, University of Naples 'Parthenope'; Henrik Lund, Aalborg University; Laura Vanoli, University of Naples 'Parthenope'

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To mitigate climate change, the European Union has proposed to reduce greenhouse gas emissions by 2030 of at least 55%, compared with 1990 value, and a long-term decarbonisation target by 2050. In this context, cities can be of high impact. Nevertheless, local energy planning is considered a voluntary task in many Countries. The lack of guidance from higher-level administrations leads to huge variety in terms of structure of the plans, while the lack of strategies in the use of local energy sources could lead to overexploiting or devaluation. For these reasons, the work proposed focuses on the investigation of the level of coordination of local energy plans with regional/national ones in the achievement of sustainability goals. The analysis evaluates the effects of the transition to smart energy cities on higher scale energy systems. The work has been performed in three steps: i. identification of the features that characterize urban energy plans to be involved when analysing coherence with higher scale plans; ii. implementation of a city level energy system model representing an Italian city for a reference year and a smart energy city scenario; iii. evaluation of the level of coordination of the scenario with higher scale plans, highlighting whether the possible divergence is the result of incompatible strategies, or it derives from the assessment of the technical feasibility of the actions involved in the plans. The tool used to model the energy system is EnergyPLAN.

Keywords: Strategic energy planning, Local energy planning, Smart energy systems, Smart energy cities, Renewable energy, Multi-scale energy planning

Gerald Birngruber did his master in Computer Science at Graz University of Technology. Currently he is working as a PhD student in the research group "Intelligent Energy Systems" at the institute of software technology.

Digital Energy Twins - Optimised Operation and Design of Industrial Energy Systems

Gerald Birngruber, Graz University of Technology; Carles Ribas Tugores, AEE Intec; Ahmed Junaid Tahir, AEE Intec; Thomas Kurz, University Leoben; Gerald Schweiger, Graz University of Technology

Gerald Birngruber (presenter)

The industry sector is one of the largest energy consumers; it will have to reduce their energy intensity and dependency on fossil fuels demands and integrate renewable energy as one mean to achieve the 1.5-2°C commitment of the Paris Agreement. A new draft of Effort Sharing Regulation specifies a 36% emission reduction for Austria by 2030 compared to 2005 for sectors that fall outside the scope of the emissions trading system. While the power sector shows significant reductions in the different future technology scenarios, the share of industrial CO_2 emissions will increase to 44% in various scenario, and it hasn't yet attracted the same level of attention than the transport and power sectors. Industrial energy systems for manufacturing are mainly designed for single supply technologies, not designed for the fluctuation of energy demand and energy supply, and thus can only react to a volatile demand and supply to a limited extent. The overall objective of Austrian Flagship-Project DigitalEnergyTwin is to support the industry with the development of a methodology and software tool to optimize the operation of industrial energy systems. The core of the project is the development of a holistic optimization approach, based on production data, historical and predictions of the existing system, both the process demand and supply level. At the conference we will present the methodology of the Digital Twin as well as results of the optimization and simulation-based analysis.

Keywords: Digital Twins, Industrial Energy Systems, Optimization

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.

How cost efficient is energy efficiency in buildings? A comparison of building shell efficiency & heating system change in the European building stock

Marcus Hummel, e-think energy research; Andreas Müller, e-think energy research; Sebastian Forthuber, TU Wien – EEG; Lukas Kranzl, TU Wien – EEG

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Mitigating CO2 emissions for space heating (SH) and hot water (HW) preparation in buildings is key for reaching climate protection targets. In this context it is important to understand meaningful balances between CO2 reduction through retrofit activities and through the change of heating systems.

In this work we develop cost optimal balances between retrofitting and heating system change for different system settings with the Invert/Opt model. The model hereby optimizes the measures applied in each building, so that the system costs for SH and HW preparation in buildings are minimized under given constraints for a given country. For each building, about 500-1000 options are considered: 4-5 building shell related measures, 15-20 heating systems, 2-3 solar thermal systems and 2-3 PV systems. We calculate scenarios for all countries of EU-27 (+ GBR, NOR, CH, ISL) reflecting a 95% reduction in CO2 emissions for SH and HW with a mix of direct and indirect RES technologies. The scenarios differ in the constraints related to the choice of building shell related measures. The goal is to analyse the cost effectiveness of CO2 reduction through retrofit activities vs. the reduction through the change of heating systems. The results show that final energy demand is declining with reduced restrictions in the choice of retrofitting measures. This indicates that a remarkable share of efficiency measures in buildings are cost efficient compared CO2 mitigation via heating system change.

Keywords: 95% CO2 reduction, European building stock, building retrofit, heating system change, building stock model, Invert/Opt

Philipp Mascherbauer is working in 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.

Investigating the demand side flexibility of the building stock

Philipp Mascherbauer, Lukas Kranzl, Technical University of Vienna

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With a growing share of volatile renewable electricity, demand response becomes increasingly important to maintain electricity grid stability. Shifting demand in the residential sector can effectively reduce demand peaks in the electricity grid. This paper addresses the following research question: How can active demand response measures of buildings with heat pumps in the residential sector affect the aggregate load profile on the national level? In order to deal with this question, an optimization model is developed. It takes the detailed building stock of a country by building archetypes into account. Occupants' behavior is considered by assigning different indoor set temperatures and days of absence. Minimizing each building types end-users' cost, assuming a dynamic electricity price function, is the optimization algorithms objective function. Thereby, the focus is on space heating, cooling, and hot water production. Non-heating induced electricity and hot water consumption is exogenously derived. Expected results include load profiles of a representative building in Austria for a particular building archetype considering the demand response of the space heating and hot water end-use. The cost reduction and the change in the load profile will be quantified. Subsequently, all buildings load profiles in a NUTS1 region are aggregated and compared to a current profile that does not consider demand response in this region.

Keywords: Energy modeling, demand response, heat pumps

Nikola Matak, mag.ing.mech, is a PhD student at the Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb (UNIZAG FSB). He is working as project manager on the projects YENESIS, COASTENERGY, JointSECAP and KeepWarm on energy planning and implementation of RES.

Selection of mitigation actions in Smart SECAPs through comparison of individual and joint implementation

Nikola Matak, University of Zagreb Faculty of Mechanical Engineering and Naval Architecture

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Climate change is one of the crucial issues of humanity in the 21st century. One of the ways to tackle this issue are local and regional initiatives, like the Covenant of Mayors, which create energy and climate plans with mitigation measures. At the development of energy plans, the most common issue is planning and preparation of reference and alternative scenarios for reduction of energy consumption and greenhouse gas emissions. The mitigation of greenhouse gas emissions (GHG) can be done either on a local or regional level through an individual or joint approach. The research aims to upgrade methods for local and regional energy planning through the choice of mitigation actions and alternative scenarios for the reduction of GHG emissions. This will be done by optimisation of the selection of mitigation measures in the case of the wider Dubrovnik area in Croatia by choosing the most suitable option for implementation comparing individual and joint approach for the planning of the measures. Also, the implementation of single and sets of mitigation measures will be compared through these two options, together with measures linked to smart energy systems such as integration of transport and energy sectors or integration of measures for building renovation with renewables production and advanced joint ownership. The results will provide the approach for reaching the GHG reduction goal of 40% by 2030 through the implementation of SECAPs on a local and regional level.

Keywords: Mitigation actions, Covenant of Mayors, local energy plans, Smart SECAP

Hironao Matsubara is chief researcher of Institute for Sustainable Energy Policies in Tokyo, Japan. His research fields are statistics database, scenario study, policy framework and business model of renewable energy. He took a degree as Doctor of Engineering from Tokyo Institute of Technology.

100% Renewable Energy Scenario in Tokyo metropolitan area with green recovery by 2050

Hironao Matsubara, Institute for Sustainable Energy Policies

Hironao Matsubara (presenter)

This study presents investigation of the possibility of 100% Renewable Energy Scenario in Tokyo metropolitan area with green recovery process by 2050. In the Zero Emission Tokyo Strategy, the Tokyo Metropolitan Government aims to decarbonize 100% of its energy use by 2050 to achieve net zero CO2 emissions by using renewable energy as main energy sources and strengthen energy efficiency. To achieve this goal, a scenario for 100% renewable energy in Tokyo is examined, which corresponds to a sustainable economic recovery so called green recovery from the COVID-19, and the potential for energy conservation and the possibility of energy conversion through sector coupling are shown. The amount of renewable energy introduced in Tokyo will be increased as much as possible in consideration of its potential for introduction in the area, and mainly solar and wind power electricity will be procured from outside the area. Electrification for the use of renewable energy electricity will be promoted, but the use of renewable heat and hydrogen and green gas/fuel from surplus electricity in the region is also envisioned.

Keywords: Renewable Energy, Green recovery, energy efficiency, scenario

Andreas Müller is an energy economist and managing director at e-think energy research. His research focuses on energy efficiency in the building stock and building retrofitting, efficient and renewable energy systems, and district heating as well as policy assessment in these areas.

How to decarbonize Munich's district heating production in long-term? Forecasting the space heating demand of Munich.

Andreas Müller, e-think energy research GmbH; Maik Günter, Stadtwerke München GmbH; *Baus Benedikt, Stadtwerke München GmbH*

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One of the decarbonization targets of Munich's utility the Stadtwerke München (SWM) is the decarbonization of Munich's district heating supply in long-term, primarily with geothermal energy. For a cost-efficient and effective expansion of the district heating network along with an increasing share of renewable energy carriers, a thorough analyse the possible development of the energy demand of and applied energy carriers in Munich's building stock is important. Therefore, the SWM did set-up a detailed model of this sector, the Modell München. It contains detailed information of buildings, including the geometry and location of each building and information such as the construction period, the currently used energy carriers for space heating and domestic hot water preparation, as well as information on future settlement areas of the city and expected population increase by postal code. For the future final energy consumption, the Invert/EE-Lab model is used. This bottom-up simulation model calculates the probabilities of retrofitting measures under different policy measures, prices and costs and the availability of energy carriers for each building. By aggregating the probabilities, the model delivers a spatial distribution of expected final energy consumption. The results of the model help SWM to better understand the dynamics of future demand and to set focused measures to reach the decarbonization target.

Keywords: Climate neutral space heating, building stock, Munich, building retrofit, heating system change, building stock model, Modell München, Invert/EE-Lab, district heating

Tobias Reum is a research associate at the Institute for new Energy Systems at the Technische Hochschule Ingolstadt, Germany. He has previous experience in heat pump development and water electrolysis and is now researching in the field of building technologies.

Experimental Investigation of a novel Hybrid Heat Pump

Tobias Reum, Mathias Ehrenwirth, Tobias Schrag, Technische Hochschule Ingolstadt

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A novel hybrid heat pump using separate evaporator and compressor circuits for both a ground and an air heat source is developed and optimized regarding technical efficiency and lower investment costs compared to a conventional ground source heat pump. Such a 'hybrid' heat pump can benefit from both heat sources and allows for a size reduction of the ground source heat exchanger in case of parallel operation and active regeneration. In this research project, the advantages of this new hybrid heat pump technology are thoroughly investigated. An adopted hydraulic scheme enabling various operation modes as well as an appropriate control strategy is developed. Finally, the energetic feasibility of these hybrid heat pumps is determined.

An appropriate laboratory test rig enables testing at realistic conditions including simulated ground and heating return temperatures as well as ambient temperatures. The novel operation strategies are analysed and optimized depending on the main influencing parameters such as the bivalence points for each heat source and parallel operation, ground source heat exchanger size, defrosting operational states and power control parameters, especially in case of low ambient temperatures.

Both energetically and in terms of investment costs, the novel hybrid heat pump is expected to be improved compared to conventional ground source heat pumps. In this paper, first results are presented.

Keywords: Hybrid heat pump, dual source, novel interconnection, experimental investigation

Daniel Trier has worked at the consultancy PlanEnergi since 2010 and is head of department at the Copenhagen office. He mixes international research projects on intelligent energy system transition with the task of assisting DH companies when establishing new renewable heat production assets.

Large-scale heat pumps for district heating – Lessons learned from real applications

Daniel Trier, PlanEnergi

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While large-scale heat pumps are often considered a well-established key technology for the coupling between the thermal and the electricity sector, such heat pumps for district heating are still undergoing significant continuous development based on the experiences from full-scale applications.

A study carried out in the framework of the IEA DHC TS3 project provides lessons learned from practical experiences as to the choice of suitable heat pump solutions depending on the DH context (local conditions, DH network, electricity market etc.) Key messages to consider in the planning and construction phase are presented as well as the impact of framework conditions on both the preferred solutions and how these heat pumps are operated with respect to the balancing services provided (and not provided) to the electricity grid. Pros and cons for the following topics are explained: a) heat sources and the types of heat pumps incl. various refrigerants, b) configurations in the local system, c) performance dependency on temperatures and thermal demands, d) economics, e) electricity grid balancing services including how this facilitates the integration of more fluctuating renewable electricity production.

Keywords: District heating, heat pumps, sector coupling, electrification

Pierre JC Vogler-Finck has a background in energy engineering and control, with an industrial Ph.D. from Aalborg University in Denmark. He works in R&D focusing on data-driven control and monitoring of building heating, aiming at improving its efficiency and integration within the energy systems.

Data-driven operation of building heating to support the energy transition at community level – Learnings from field applications

Pierre JC Vogler-Finck, Neogrid Technologies ApS

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Energy efficiency and flexibility of the demand side are two essential enablers of the green transition. In Europe, the building sector uses about 40% of energy (with significant fraction of it to space and water heating) with a major contribution potential on these two enabling levels. For over a decade, Neogrid Technologies has been active in the data-driven heating operation. Its solutions focus on online data collection, intelligent operation monitoring and predictive control, with an aim to unlock energy efficiency and flexibility.

This presentation focuses on field experience from operating these data-driven technologies in buildings supplied by either district heating or electricity, where the aim is to establish an intelligent coupling between building operation and the energy network. A particular attention will be given to applications at the community level, and the challenges of delivering these solutions to the market in the current context.

Keywords: energy efficiency, energy flexibility, digitalisation, control technology, building heating operation, data-driven solutions, control

Felix Agner joined the department of automatic control in January 2020 as a PhD student with a MSc in Engineering Physics from Lund University. He is working in the departments project on scalable control and in particular its application in the area of demand response in the energy sector.

Improving robustness to peak load conditions in district heating networks through scalable control coordination subject to network constraints

Felix Agner, Lund University

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In the structure of current district heating systems, central distribution pumps are commonly used to drive a flow through the network. This structure causes an issue where if the circulation is too great, pressure losses due to friction grow large. When this happens, usually in peak conditions, peripheral units (customers) find that they cannot satisfy their flow requirements while central units do not experience any issues. This work aims to increase fairness in distribution through a coordinating control strategy. Distributing this flow deficit over many units rather than a few units can increase the system robustness. This would allow for system designers to keep costs down by designing the system with lower peak loads in mind. Previous work in advanced controllers mainly focus on MPC-structured controllers that depend on advanced system models and optimization techniques. System models, especially encompassing models of the network, can be hard to obtain and maintain. Optimization-based control can also be hard to implement for systems with a large number of signals. This work therefore focuses on using simple controllers for individual units and then coordinating them. The advantage of this approach is lower dependence on modelling and higher scalability for growing systems. A hydraulical model of the distribution system is used to analyze the control strategy and simulate the system, demonstrating how the methodology can be used.

Keywords: district heating, automatic control, demand response

Jakob Binder, B.Sc, is responsible for District Heating and Cooling at AEE - Institute for Sustainable Technologies (AEE INTEC).

Interconnection and smart control of district heating networks for increased flexibility

Joachim Kelz, AEE - Institute for Sustainable Technologies; Jakob Binder, AEE - Institute for Sustainable Technologies; Ingo Leusbrock, AEE - Institute for Sustainable Technologies; Valentin Kaisermayer, BEST - Bioenergy and Sustainable Technologies GmbH; Daniel Muschick, BEST - Bioenergy and Sustainable Technologies GmbH; Markus Gölles, BEST - Bioenergy and Sustainable Technologies GmbH; Wolfgang Rosegger, Schneid GmbH; Günter Beck - Beck & Partner KG

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The district heating supply of the Leibnitz area faces a massive expansion, which shall be achieved with 100% renewable heat sources. Two operators deliver heat from two biomass heating plants as well as waste heat from a biogas and a rendering plant combined with a natural gas boiler. Interconnecting networks can save costs of peak load or backup boilers, free up production capacity for network expansion, increase flexibility and security of supply of the network. In the present case also CO2 emissions can be reduced. Thus, the two operators started a cooperation by interconnecting their networks with a bi-directional heat transfer station and setting up an overall control system.
The supply side is managed by an Energy Management System (EMS), coordinating the production units and the heat exchange between the networks. The Demand Side Management aims at smoothening the load on the consumer side. A main challenge of implementing the new procedures was defining data interfaces, fallback scenarios and security options. With the implementation of the EMS, the share of waste heat is maximized and the use of biomass is optimized, while the operation of the gas boiler is minimized. As a result, CO2 emissions as well as operating costs can be reduced. First evaluations show different cooperation possibilities, depending on the optimization goal. The talk will give an overview of the technical solution, the savings potential realized and the challenges which have arisen.

Keywords: district heating, interconnection, bidirectional heat transfer station, smart control, unit commitment, energy management system, demand side management, multi-owner

Luca Casamassima is a PhD researcher at the TU Wien in the Energy Economics Group. He is part of the SMART-BEEjS consortium, a group that studies and promotes Positive Energy Districts across Europe. He's currently researching how to transition the current building stock for the future 4th Gen District Heating.

A proposed Pathway to future-proof current building stock for upcoming 4th generation district heating in the scope of Positive Energy Districts

Luca Casamassima, Lukas Kranzl, Economic Energy Group - Technische Universität Wien

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Currently, District Heating systems are mostly supplying heat at a fairly high temperature. Lowering the temperature will benefit the system, allowing higher renewable penetration and lower distribution and transmission losses. This paper analyses the transition from the residential customer side perspective for various building typologies in a Mediterranean and continental climate. The aim is to understand the energy efficiency measures that allow for low-temperature heating in buildings when climate conditions and the building stock's initial state vary significantly. Hence, in this paper, the building is the system boundary of the analysis. U-values, total and specific heat demand will be compared in various scenarios to achieve this goal. First, this paper reviews current space heating technologies by collecting technical data such as emissivity, inlet and outlet temperature. Further, a review of the buildings archetype is performed to categorise the mentioned parameters by age, typology and geographical location. This work is done parallel to the simulations performed with EnergyPlus/OpenStudio to establish each building archetype's baseline. Finally, the energy efficiency measures are applied to reach thermal comfort with low-temperature heat. An analysis of the cost of lowering supply temperature in buildings from a customer perspective is carried out to understand possible pathways and their economic viability.

Keywords: Positive, Energy, Districts, Heating, Low-Temperature, Building stock, Retrofitting

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.

Performance measurement and detailed modelling of an existing neutral-temperature district heating network based on decentralized heat pumps

Marco Cozzini, EURAC Research

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Thermal networks operated at neutral (i.e., close to ambient) temperature offer an ideal solution for the exploitation of low-temperature sources. A network of this type started its operation in 2018 in Ospitaletto, Italy. The system is supplied by a combination of aquifer wells (at about 15 °C) and waste heat from cooling towers (recovered at about 25 °C), it runs the network (about 2 km of length) with a variable temperature depending on the active source, and it supplies four large user substations endowed with heat pumps (HPs). In consideration of the operating temperature, part of the network is built with non-insulated plastic pipes. Different sets of monitoring data are analysed here, assessing the performance of both single user substations and of the entire system. Moreover, the results are used to validate a simulation model yielding the operating conditions at the main network nodes. The comparison is focused on the network behaviour, including thermal losses and pumping consumptions. Peculiarities related to the use of non-insulated pipes are highlighted.
The coefficient of performance (COP) observed in HP substations exhibits an average value of around 3.6, while the overall seasonal performance factor (SPF) including network pumping consumptions is of the order of 3.1. The significant share of electricity in this system makes it an interesting playground for sector coupling considerations, which are briefly discussed along with its expansion potential.

Keywords: District heating and cooling, heat pumps, waste heat, monitoring, modelling

Christian Engel works since 1980 in the district heating pipe industry in close cooperation with European energy suppliers. He is member of CEN TC 107 for pre-insulated pipe systems; Expert at IEA-DHC TS2 and representative of Austroflex in Euroheat & Power / Brussels.

Green deal impact of DHC networks: how best preforming piping systems make DHC even more attractive

Christian Engel, Austroflex Rohr-Isoliersysteme GmbH

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DHC networks are an important cornerstone within the European green deal. This session will cover how especially new or renovated networks can contribute to improving and decarbonising of heating and cooling!

The author has 40 years of experience in district energy networks and will show what todays best performing piping systems can contribute to improve network performance in relation to operation, heat loss, lifetime, CO2 emissions and economy of DHC investments. The focus is given on networks that can be realised either with conventional steel or plastic pipes. This contribution provides an overview of the economic and ecological benefits, based on investigations made between 2018 and 2020 on various DH networks. Additionally, the CO2 effect until 2030 will be discussed.

Keywords: Low-temperature district heating, Potentials and effects of series 3 and equivalent piping systems, CO2 reduction potential, Energy saving potential, steel vs plastic networks

Jonas Gottschald has been a research assistant at the University of Applied Sciences Düsseldorf in the Center for Innovative Energy Systems for 8 years. There he works on research projects in the field of renewable energies and energy efficiency.

Data-based multi-criteria operational optimization of district heating supply while reducing balancing energy

Jonas Gottschald, Marius Reich, Mario Adam, University of Applied Sciences Düsseldorf

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The combination of several heat and power generators with different energy sources and a high share of renewable energies enables flexible, climate- and cost-friendly heat supply concepts for districts. Recent research demonstrates the advantages of multilevel nonlinear models for mapping and predicting the complex thermal behavior of energy systems. Combined with metaheuristic optimization, both environmental and economic improvements in operation are achieved. In Germany, electricity generators or consumers of high power have to announce a schedule the day before and trade electricity on the market accordingly in advance. The time lag leads to deviations between planned and actual operation due to forecast uncertainties. This leads to additional costs that are difficult to calculate due to necessary compensation to stabilize the grid. With the aim of reliably reducing costs and emissions even under uncertain boundary conditions, an extended modeling and optimization approach based on machine learning methods is presented. The combination of a schedule generation for the following day (offline optimization) with a continuous adjustment of the operation during the fulfillment day (online optimization) shows significant improvements regarding costs and emissions in simulations. Further improvements can be expected through the targeted integration of forecast uncertainties into the optimization.

Keywords: district heating, machine learning, nonlinear approximation, optimization, hybrid heat supply, low temperature district heating, balancing energy

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

Design of Two Pipe District Heating and Cooling Networks using Ring and Meshed Network Configuration – A Case Study

Joseph Maria Jebamalai, Department of Architecture and Urban Planning, Ghent University; Jelle Laverge, Department of Architecture and Urban Planning, Ghent University; Kurt Marlein, Comsof

Joseph Maria Jebamalai (presenter) joseph.jebamalai@comsof.com

District heating systems are evolved from steam systems (1st generation) to low temperature water based systems (4th generation) and pilot projects are coming out on ultra-low temperature systems with building side heat pumps (5th generation). Some notable features of the future district heating and cooling (DHC) networks are integration of distributed low temperature sources, combined DHC systems, integrated heat and cold storage, 2 way DHC to connect prosumers, and usage of building side heat pumps. The design of large scale DHC networks with all these features poses many challenges. In this paper, a method to design two pipe DHC networks with prosumers using ring and meshed network configuration will be described. The ring network configuration has two rings (one hot and cold ring) where the hot ring is connected to the heat source and heat storage and the cold ring is connected to the cold source and cold storage. The demand points are connected to the hot and cold ring and each demand point has a heat pump and circulation pump to extract and deliver heat and cold from/to the ring. This ring configuration allows the prosumers to exchange heat/cold with other buildings through the ring. The meshed network configuration has a meshed structure/ interconnections in the ring configuration. The developed method is implemented in the DHC design tool, Comsof Heat and a case study is developed to design and compare these two configurations and study the effect on the network cost.

Keywords: Ultra-low temperature systems, Combined heating and cooling, Prosumers, Heat pumps, Ring network configuration, Meshed network configuration

Hanne Kauko has a PhD in experimental material physics. Since 2014 she has been working as a researcher at SINTEF within the field of energy efficiency, with special interest in 4th generation district heating, thermal storage, and energy system modelling.

Investment analysis of a local energy system with seasonal thermal energy storage

Hanne Kauko, Dimitri Pinel, Ove Wolfgang, SINTEF Energy Research

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Furuset is a suburb in Oslo, Norway, with 2800 homes built in the 70s. Within the coming years, the area will be extended with several new apartment and commercial buildings, as well as arrangements for green mobility. To minimize the total and peak energy demands from the surrounding energy system, a large-scale demonstration project of a micro energy system combining various solutions for local production of heat and electricity has been launched.

For heat supply, the plan is to establish a low-temperature district heating (DH) network in combination with a high-temperature seasonal thermal energy storage. The seasonal storage will store excess heat from a nearby waste incineration plant in the summer, to supply heat to the buildings at Furuset in the winter. The heat demand of the existing buildings is currently covered by direct electric heating, which is a common solution in Norway. The new and some of the existing buildings will be connected to the planned local DH network.

The aim of this study is to demonstrate the benefits of DH through avoided costs in power supply. This topic is becoming increasingly relevant in Norway with the high ambitions for electrification of the transport sector. Using an optimization tool for investment planning of local energy systems with multiple energy carriers, three different heat supply solutions have been evaluated: direct electric heating, high-temperature DH, and low-temperature DH with seasonal thermal energy storage.

Keywords: low-temperature district heating, seasonal thermal energy storage, energy system modelling

Henrik Lund is listed among ISI Highly Cited researchers ranking him among the top 1% researchers in the world within engineering. He is Professor in Energy Planning at Aalborg University and Editor-in-Chief of Elsevier International journal ENERGY.

Transition to 4th Generation District Heating and Motivation Tariffs

Henrik Lund, Aalborg University; Jan Eric Thorsen, Danfoss; Steen Schelle Jensen, Kamstrup; Flemming Pentz Madsen, Vaarst Vestervang

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The implementation of 4th generation district heating involves adjustments in the demand side to allow for low temperature supply. In order to facilitate such changes district heating supply companies in recent years has introduces tariffs with penalties to high return temperatures and benefits to low return temperatures. This paper describes the case a housing community of 17 buildings in their attempts to adjust to such tariffs as an integrated part of connecting to district heating in 2020. Replacing hot water tanks with flow heat exchangers and introducing smart meters resulted in abilities to lower the return temperature from around 40 C to around 30 C. Based on such efforts this paper discuss the fairness and the effectiveness of the tariffs and give recommendations to improve it.

Keywords: 4th Generation District Heating, Low temperature District Heating, Smart Energy System, Demand side management. Motivation Tariffs

Kristina Lygnerud is Associate Professor in Industrial and Financial Economics at Halmstad University. She also works as Energy Department Manager at the Swedish Environment Institute (IVL). Research focus is business model innovation in district energy.

Implementation of low temperature district heating

Kristina Lygnerud, Halmstad University; Sven Werner, Halmstad University; Svend Svendsen, DTU; Roman Geyer, AIT; Harald Schrammel, AEE; Dietrich Schmidt, Fraunhofer; Frank Dammel, Darmstadt University; Helge Averfalk, Halmstad University; Johannes Oltmanns Darmstadt University and others...et al.

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During three years, a team of 17 researchers from 5 EU countries have worked on condensing information from early, low temperature district heating installations (IEA Annex TS2). We have identified a gross list of 165 installations world -wide, confirming that this kind of implementation is a trend. Information has been collected to generate a comprehensive guidebook covering different parts of the heating value chain. Economic benefits and the competitiveness that can be gained from low temperature installations are addressed. How to adjust the building for lower temperatures as well as the heat supply and distribution network are explained.

We highlight that in some district heating cities the transition from high to low temperatures has already been initiated and that one common denominator for all is to lower the network temperatures. We find that it is not technical barriers that hinder rapid implementation of low temperature solutions. Instead, it is the knowledge on how to build the new systems, how to combine existing technology solutions like heat pumps with low temperature heat recovery into existing or new distribution networks and buildings. Also, the tradition to focus on technology before business case is cumbersome leading to a situation where conventional district heating business models are applied onto low temperature installations thereby eroding the competitive advantage that the low temperature installations can bring to a district energy portfolio.

Keywords: Low temperature, Guidebook, Buildings, Systems, Demosites, Competitiveness

Yannis Merlet currently works at CEA-Liten with multi-objective optimization applied to district heating networks and used such methods previously with building energy systems.

Formulation and assessment of multi-objective sizing: application to low temperature District-Heating networks

Yannis Merlet, Roland Baviere, Nicolas Vasset, Univ Grenoble Alpes - CEA, LITEN, DTCH, labo

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As District Heating (DH) networks progress towards lower temperature, inspired by the 4th and 5GDHC concepts , devising an effective methodology for the sizing of a network at the system level is becoming a challenge. Various approaches, proved that the use of optimization methods was quite relevant with that aim.

We developed a framework enabling the optimal sizing of the distribution pipe diameters in a complex DH system using multi-objective optimization. In contrast with other fields of research such as water distribution system or transportation networks, we did not find in the literature validation cases to use on our framework. Consequently, we propose in this work a generic validation and verification methodology, which we apply to our optimal sizing framework. The latter focuses on simple problems such as a linear network, a loop network and branch network that allow the direct comparison with a reference solution for the validation of the approach.

As a result, our framework was able to identify critical routes in the DH network and to generate optimal solutions close to the reference solution for each case of interest. Those solutions showed a decrease, up to 15%, of operational and investment cost compared to classical sizing methods using global cost minimization for each pipe independently. Moreover, by increasing the number of consumers in each type of problem, we propose a first approach of the scalability of our optimal sizing method.

Keywords: district heating, multi-objective optimization, sizing, simulation, validation

Ali Moallemi graduated in Mechanical Engineering and obtained his PhD at UFMG in Energy and Sustainability with thesis title of ”Thermodynamic Modeling of a 4GDH System in Brazil”. Currently, he is a post-doc researcher at Lund University and studies on the 4GDH systems, specifically in COOL DH Project.

COOL DH: A Pioneering Project to Implement Low Temperature District Heating (LTDH) Systems As an Integrated Part of Smart Energy Systems

Ali Moallemi, Jens Klingmann, Per-Olof Johansson Kallioniemi, Lund University

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Cool DH is an EU funded project to enhance the Technology Readiness Level (TRL) of LTDH networks from single components to a real complete demonstration. Actually, the objective of COOL DH is to demonstrate technologies to utilize low temperature waste heat for implementing LTDH systems. The demonstrations compromise two full scale LTDH grids in two cities Lund in Sweden and Høje-Taastrup in Denmark and one Ultra-Low Temperature DH (ULTDH) system in Lund to supply Domestic Hot Water (DHW) devoid of legionella risk. In such demonstration a higher share of renewables and waste heat can be increased by lowering DH temperatures. For this purpose, heat pumps are used to increase quality of low-grade waste heat. Renewable Energy Sources (RES) provide electricity of the network mainly driven by PhotoVoltaic (PV), hydropower and wind. The project designed and started in 2017, heat recovery process started in 2020 and the project will be completely under operation, monitoring, and evaluation in 2022. Construction of new buildings in Lund has been started in 2019 while LTDH in Høje-Taastrup mainly applied to existing buildings that are being renovated. As a result, this project as a part of smart thermal energy network can be integrated into a smart energy system to make the cities more efficient in terms of energy consumption, environmental and social impacts regarding economic aspects. The replication of this project can be facilitated by experiences and lessons learned of that.

Keywords: COOL DH, Heat Pump, Heat Recovery, Low Temperature District Heating, LTDH, Renewable Energy, Waste Heat

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.

A real-life data driven model for district heating

Kevin Naik, Prof. Anton Ianakiev, Nottingham Trent University

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Modern district heating schemes like 4th generation Low Temperature District Heating (LTDH) and the emerging 5th generation district heating, due to their inherent low carbon emissions, are going to play vital role in the decarbonisation of UK energy and will help achieving zero carbon status by 2050. Modern district heating schemes are more sensitive to variation of the heating load and require more precise heat demand prediction. It plays an important part in increasing the overall efficiency of these systems. Accurate heat demand prediction is facilitated by the development of advanced simulation systems based on the increasing computational power and innovative machine learning algorithms. This paper discusses a novel approach to utilise real-life data to create individual heat profile for district heating users and generate realistic individual heat demand of the heating system and set it in optimum heat generation mode.

Keywords: Heat Demand, Machine Learning, Data-Driven

Docent, senior researcher **Ieva Pakere** has wide experience in energy production from RES and different heat supply aspects. Main research areas are district heating optimisation, solar thermal and power systems, mathematical modelling and energy efficiency improvement of technological processes.

Pathways toward carbon neutral 4th generation district heating system in Latvia

Ieva Pakere, Andra Blumberga, Armands Grāvelsiņš, Signe Allena-Ozoliņa, Dzintars Jaunzems, Dagnija Blumberga, Riga Technical University

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Recent studies show that district heating (DH) is one of the pioneers toward carbon neutrality as it allows to increase energy efficiency and decrease primary energy sources. Innovative technological concepts such as renewable power to heat, sector coupling, and waste heat utilization allow reaching new goals toward complete decommissioning of fossil resources. The study compares two different modeling methods which allow identifying main driving forces and barriers to reach carbon-free DH. The system dynamic model includes different dynamic components such as decision-making elements, the impact of information and knowledge on the operation of the system, etc. A bottom-up optimization model Times seeks the most beneficial strategy for the energy sector to cover energy demand. Both model includes traditional and innovative heating technologies and solutions, spatial distribution of heat demand and cost/benefit analyses. Comparison of two different methods allows identifying different strategies towards carbon neutrality by taking into account support policies for renewable energy sources and more efficient heat generation and distribution. The additional scenario involves limitations for wood biomass use in the energy sector in order to increase added value from this resource. Use of different methodologies ensures detailed validation of obtained forecasting results as well as highlights main influencing factors acting as levers toward carbon neutrality.

Keywords: system dynamics, Times modelling, 4th generation district heating, carbon neutrality

Rémi Patureau is currently a PhD student. The subject of the PhD is ”Development of design methods of new Heating & cooling district networks”.

Comparison of two district heating and cooling designs based on dynamic simulation

Remi Patureau, CES - Mines Paristech/Efficacity; Cong-Toan TRAN, CES - Mines ParisTech; Valentin GAVAN, ENGIE Lab CRIGEN; Pascal STABAT, CES - Mines ParisTech

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In the recent years, many new designs of District Heating and/or Cooling (DHC) have been developed and implemented with the aim of improving their overall performance. However, few studies were conducted to compare the performances of those designs on a same district. This paper aims to compare two DHC designs, inspired by two new networks in operation. The case study on which these two DHC designs are assessed is a small district recently built, composed of residential and commercial buildings. The two DHC designs exploit a renewable and local source of energy, the sea water. They provide both heating and cooling energy: the first one via a centralized production using heat pumps for simultaneous heating and cooling, chillers, and a boiler as a backup; the other one via decentralized productions using heat pumps for simultaneous heating and cooling and heating storage units for domestic hot water needs. The two networks are modelled and simulated using the language Modelica, over a period of a year. The simulation is validated using measured data. Then a comparison is performed considering the energy consumed to meet the buildings' needs. An analysis carried out on three typical days (peak winter, mid-season, and summer) shows the differences of the network performances according to the weather conditions.

Keywords: Comparison of two district heating and cooling designs, Modelling and simulation using the language Modelica

Stefan Puschnigg is a researcher at the Department of Energy Technology. His main activities are techno-economic and environmental assessments of sustainable energy projects. Research includes excess heat utilization, energy cooperation, business models, district heating, sector coupling and energy flexibility.

An analysis of cascaded low-temperature sub-networks in existing district heating networks

Stefan Puschnigg, Energieinstitut an der Johannes Kepler Universität Linz; Gabriela Jauschnik, Energieinstitut an der Johannes Kepler Universität Linz; Hanne Kauko, SINTEF Energy Research; Benedikt Leitner, AIT Austrian Institute of Technology GmbH; Simon Moser, Energieinstitut an der Johannes Kepler Universität Linz; Ralf-Roman Schmidt, AIT Austrian Institute of Technology GmbH; Andres Siirde, Tallinn University of Technology; Anna Volkova, Tallinn University of Technology

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The vast majority of today's district heating networks (DHNs) operate on relatively high temperatures, typically 90-130°C supply and 50-70°C return flow. Low temperature district heating networks (LTDHNs) operating at supply temperatures of 50-70°C are more efficient and have the advantage that renewable heat sources or low temperature waste heat can be utilized. Although transforming high temperature DHNs to LTDHN offers opportunities for decarbonization, the conversion into a LTDHN is associated with great difficulty and effort. As a potential pathway of transformation, this paper analyses the integration of low-temperature sub-networks into the return flow of an existing large urban DHN, thus creating a sub-LTDHN. As a result, this will reduce the return temperature of the overall DHN and may improve its efficiency and sustainability. Despite the potential advantages, there are several technical, legislative, and economic issues related to the implementation of sub-LTDHNs. The results of this paper provide a detailed evaluation on technical and operational conditions as well as on novel business models for sub-LTDHNs. Technical solutions for the connection and control are examined using dynamic simulations. Large scale replication and interaction of sub-LTDHNs, including a techno-economic analysis for assessing the transformation pathways for the overall DHN using sub-LTDHN, are evaluated.

Keywords: cascading, low-temperature, district heating, sub-network, energy efficiency, decarbonization

Dietrich Schmidt is affiliated to the Fraunhofer Institute for Energy Economics and Energy System Technology (IEE) in Kassel/Germany and works as head of Department Heat and Power Systems within the research and development division on Energy Economy and Grid Operation.

Low temperature district heating as a proven and market ready technology – Case studies of IEA DHC ANNEX TS2

Dietrich Schmidt, Fraunhofer IEE; Kristina Lygnerud, Halmstad University; Sven Werner, Halmstad University; Roman Geyer, AIT; Harald Schrammel, AEE; Dorte Skaarup Østergaard*, DTU; Oddgeir Gudmundsson, Danfoss*

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The introduction and application of new concepts and technologies such as low temperature district heating (LTDH) often face concerns if it is actually feasible and working in a reliable way. Low temperature district heating is recognized as a key technology for the (cost-) efficient integration of renewable energy and waste heat sources in our energy systems. This technology is of major importance for the decarbonisation of the heating sector in many countries, as indicated by a large number of energy system studies.
Within the IEA DHC Annex TS2 already realised low temperature community energy system concepts as well as planned or designed systems are identified and visualised in the project. Furthermore, projects showing an innovative use or operation of buildings are included. The different projects are assessed and compared. From about 150 demonstrators included in the DHC Annex TS2 a selection of 15 are analysed in detail with regard to which elements of new knowledge they can generate. The paper presents and discusses the results of the collaborative research work on the analysis of case studies within of the IEA DHC Annex TS2 on Implementation of Low Temperature District Heating Systems. By doing so, real evidence is given that LTDH is a proven and market ready technology, which works under various boundary conditions and in many countries.

Keywords: low temperature district heating; case studies; innovative heat supply

Artem Sotnikov has MSc in Mechanical Engineering and in Solar Energy Engineering. Since 2017 he works as a research associate at the Institute of Building Technology and Energy, Lucerne University of Applied Sciences and Arts. His main activities are thermal simulation of buildings and district heating networks.

Hydrothermal challenges in low-temperature networks with distributed heat pumps

Tobias Sommer, Lucerne University of Applied Sciences and Arts; Artem Sotnikov, Lucerne University of Applied Sciences and Arts; Matthias Sulzer, Swiss Federal Laboratories for Materials Science and Technology; Volkher Scholz, Belimo Automation AG; Stefan Mischler, Belimo Automation AG; Behzad Rismanchi, The University of Melbourne; Kristian Gjoka, The University of Melbourne; Stefan Mennel, Lucerne University of Applied Sciences and Arts

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Low-temperature networks in combination with heat pumps allow for efficient heating and cooling of buildings and thermal energy exchange between buildings. Thus, low-temperature networks are a central element in any strategy aiming to reduce our carbon footprint. However, they are far more complex in operation than traditional district heating networks at high temperatures. This operational complexity has hindered market diffusion. To allow for simplified planning of future networks, we deliver an extensive discussion on the requirements of real-world implementations of low-temperature networks. The focus is laid on the operation of heat pumps and their interaction with the network. The term "agent authority" is introduced to quantify flow variations in the network caused by network substations interactions. Control strategies are suggested to ensure robust heat pump performance and a specific control strategy using a sensor/valve combination is suggested. Finally, two case studies for low-temperature networks are presented. The first one describes how flow optimization affects electrical demand in a low-temperature network in Valais, Switzerland. The second incorporates this paper's findings into a decision matrix for a planned low-temperature network in Melbourne, Australia.

Keywords: district heating networks, district cooling networks, district energy networks, heat pump, hydraulics, hydronics, agent authority, pressure surges

Jan Eric Thorsen is the 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.

Insights on domestic hot water consumption for multi flat buildings

Jan Eric Thorsen, Danfoss A/S; Frederik Stjernholm Busk, TREFOR Varme A/S; Firat Günyel, Hillerød Forsyning; Mikko Wahlroos, Leanheat Oy

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Smart control of the energy system is highly in focus today. The aim is to improve the performance of the energy system by a holistic control approach aiming at a smart sector integration. At the heat consumer end of the district heating system heavy focus is on the heating system, providing e.g. energy flexibility based on the thermal capacity of the building as well as energy savings. Besides this, there is the domestic hot water consumption. This part opens the opportunity as well for load shift and peak load management. For getting the understanding of the domestic hot water load pattern, which is the basis for investigating the potential for smart control e.g. by load shift, detailed measurements are made for 5 locations focusing on multi flat buildings. This presentation includes the measurements covering the typical daily, weekly, and seasonal behaviors of domestic hot water consumption including a qualitative discussion of the measured data. The work is performed as a part of the Innovation Fund Denmark funded project HEAT 4.0.

Keywords: Domestic hot water, Consumption, Seasonality

Marc-André Triebel is researcher at Fraunhofer ISE since 2016 and has a background in mechanical engineering and energy engineering. He is analysing, developing and optimising energy systems for districts, cities, and regions around the world with a focus on sector coupling and integrated solutions.

Techno-Economic and Ecological Evaluation of Different District Heating Network Generations for two German Districts

Marc-André Triebel, Annette Steingrube, Gerhard Stryi-Hipp, Fraunhofer Institute for Solar Energy Systems ISE; Daniel Siejak, Schäffler sinnogy;

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The simulation-based case study conducts a techno-economic and ecological evaluation of different scenarios of 3rd to 5th generation district heating networks (DHN) for Patrick-Henry-Village in Heidelberg and Pfaff-District in Kaiserslautern, both located in Germany. The investigated networks are either supplied by heat plants (3rd gen.), carbon-neutral industrial waste heat (4th gen.) or ambient heat (5th gen.) and supply the heating demand of refurbished and new buildings either directly or via intermediately operated heat pumps. The economic evaluation points out that 4th gen. DHN have equal to lower operational costs compared to the 3rd gen. while the operation of 5th gen. DHN appears to be uneconomical. The profitable operation of the 5th gen. DHN can be achieved by additionally supplying the cooling demand of the buildings and considering subsidies and avoided CO2-emission costs but is still outperformed by 4th gen. When comparing the CO2-emissions of the operation, the 4th gen. shows a reduction potential of 54-91% compared to the 3rd gen. The results lead to the conclusion that 4th gen. DHN represent an economic and eco-friendly alternative to older network generations. Furthermore, CO2-emissions costs, integrated solutions covering heating and cooling demand, and incorporation of on-site renewable electricity generation can promote the profitable and climate-neutral operation of low temperature heating networks and support the utilisation of ambient heat.

Keywords: District Heating Network, District Heating and Cooling Network, Low-Ex District Heating Network, CO2-Emission Costs

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.

Competitiveness of individual heat pumps in the Baltic states

Anna Volkova, Kertu Lepiksaar, Henrik Pieper, Tallinn University of Technology

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District heating (DH) allows to integrate more renewable energy sources due to the possibility of using existing infrastructure and storage capacity. However, no existing DH infrastructure exists for new development areas. In addition, heat demands of newly built areas are often lower than those of the existing building stock. This affects the linear heat density (MWh/m) covered by DH and consequently the cost of heating.

In this study it is analysed whether a new low-temperature DH network is more competitive and worth the investment than individual heating solutions such as individual heat pumps (HPs). Economic and environmental impacts are investigated for the Baltic states. Aspects such as emissions related to renewable heat generation for DH and non-renewable electricity consumption by individual HPs are compared. Biomass boilers and CHPs are considered as central plants, while air-source and ground-source HPs are investigated as individual solutions for typical new development areas in the Baltics.

The results show that individual HPs are competitive with low-temperature DH in apartment buildings in Estonia and Latvia, but not in Lithuania due to low DH prices. The investment into new DH infrastructure will account for a higher share of the total costs when the heat density is lower. Emissions from individual HPs in Estonia are higher than for low-temperature DH, due to currently high emissions from electricity generation caused by oil shale.

Keywords: heat pump, low temperature district heating, levelized costs, renewable energy

Sven Werner has been active in district heating research since 1978. He is co-author of international textbook about district heating and cooling. He retired in 2018 but is still curious in district heating and cooling.

Network configurations for low-temperature district heating

Sven Werner, Halmstad University

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Six different groups of typical network configurations for low-temperature heat distribution are presented together with fourteen associated variants. These configurations have been identified from implemented projects performed by early adopters of low-temperature heat distribution.

The six configuration groups are classified into two main groups: warm and cold district heating systems. In warm systems, the supply temperatures are high enough to deliver heat for typical heat demands in buildings without any additional heat supply in the buildings. In cold systems, ultra-low supply temperatures are applied. Some additional heat supply is then required in the customer buildings to meet the typical temperature demands. In low-energy buildings, the typical thermal load with the highest temperature demand is the preparation of domestic hot water, requiring a supply temperature of at least 50°C. Hence, supply sources below 50°C can be classified as ultra-low supply temperatures in cold district heating systems. Hereby, supply temperatures above this temperature are used in warm district heating systems.

The six configuration groups are presented in detail together with their group affiliations and main features, including configuration layouts, characteristics, typical temperature levels, some implemented installation examples, and advantages/disadvantages. Temperature levels for supply and return temperatures are expressed as annual time-averaged values.

Keywords: Network configuration, low-temperature, district heating, decarbonisation

Meng Yuan is a PhD fellow at China University of Petroleum (Beijing). She works with the modelling, optimization, and analysis of smart energy systems and 4GDH.

District heating in 100% renewable energy systems: Combining industrial excess heat and heat pumps

Meng Yuan, Department of Planning, Aalborg University, China University of Petroleum-Beijing; Jakob Zinck Thellufsen, Department of Planning, Aalborg University; Peter Sorknæs, Department of Planning, Aalborg University;, Henrik Lund, Department of Planning, Aalborg University

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The literature emphasizes the important role of industrial excess heat (IEH) and heat pumps (HP) in future 4th generation district heating and smart energy systems. However, they can potentially have negative or positive effects on the integration of renewable energy sources (RES). It is necessary to find a trade-off between IEH and HP in the transition towards a 100% renewable energy system yet has not been discussed in the literature. This paper presents a comprehensive technical-economic analysis for the optimal district heating (DH) strategy in a 100% renewable energy system. It is conducted based on a novel hybrid methodology framework that couples hourly smart energy system simulation, multi-objective optimization, and multiple-criteria decision making. The optimal share between IEH and HP and associated RES capacity can be determined considering the preferences of policymakers. A scenario for 2050 for Aalborg Municipality in Denmark is used as a case study. Results show that an appropriate mix of IEH and HP, 40% and 20% respectively in the DH supply, should be employed to obtain a balanced near carbon-neutral system with the least cost. Also, the cross-sector effective interactivities between the DH network, power grid, and gas grid are revealed in the smart energy system context. The proposed framework is designed in a general way that can be used in other cities, regions, or countries.

Keywords: 4th generation district heating; Industrial excess heat; Heat pumps; Smart energy systems; 100% renewable energy systems; EnergyPLAN

Through several years of research, **Dorte Skaarup Østergaard** has specialized in district heating with focus on how to reduce district heating temperatures. Her main field of interest is heating consumption in buildings and building installations for low-temperature district heating.

Combined district heating and cooling – which solutions are available and are they applicable in a Danish context?

Dorte Skaarup Østergaard, *PlanEnergi; Daniel Trier, PlanEnergi; Kim Sørensen, Aalborg University, Department of Energy Technology; Mads Pagh Nielsen, Aalborg University, Department of Energy Technology; Alessandro Maccarini, Aalborg University, Department of the Built Environment (AAU BUILD); Alireza Afshari; Aalborg University, Department of the Built Environment (AAU BUILD)*

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An overview of possible designs of a combined district heating and cooling system in Denmark is presented incl. a discussion of whether such systems are feasible in Denmark today. The presentation is based on the results obtained in the KOHESYS project which aims at analyzing the technical and economic feasibility of supplying heating and cooling to a new built area in Køge (Denmark). The area is to be developed during the next years and will include a few large office/service buildings and a residential area with row houses and apartment buildings. It is a groundwater sensitive area and it is located close to a wastewater heat source and an existing district heating network. Based on this setting, some of the main questions that the project team try to answer are: Is there a demand for comfort cooling in new built dwellings in Denmark? If so, is the cooling demand large enough to make it feasible to include district cooling or recover the excess heat from cooling services? Which technical in-house installations are necessary to supply the end-users with both heating and cooling, and how does these affect the requirements for the district heating and cooling network? Are the necessary technical solutions, such as relevant heat pumps, available today? Lastly, is the concept feasible compared to a more traditional district heating solution? The questions are answered through building simulations, assessment of technical installations, and an overall feasibility study.

Keywords: Cold district heating, ambient-temperature district heating and cooling, 5th generation district heating, low-temperature district heating, cooling demands, heat pumps

Annika Boldrini is a PhD candidate whose work focuses on the coupling of the power and heating sectors. Specifically, her interest lies in the flexibility that can be exploited within the heating sector to favour the integration of intermittent power sources.

On the role of district heating systems to provide balancing services in the EU

Annika Boldrini, Joint Research Centre — European Commission and Utrecht University; Juan Pablo Jimenez Navarro, Joint Research Centre — European Commission; Wina Crijns-Graus, Utrecht University; Machteld van den Broek, University of Groningen

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European electricity markets ensure the match between supply and demand at all times. Due to its time scale operation, the balancing market is the last resource to achieve so and, thus, ensure the grid frequency. The increasing share of wind and solar capacity in the power system intensifies the demand for flexibility. District heating systems (DHs) are recognised as potential sources of flexibility if interface technologies are in place like CHP or power-to-heat (P2H), together with thermal storage. This paper, based on available scenarios, estimates the technical potential contribution of DHs to the capacity markets of frequency containment reserves (FCR), automatic and manual frequency restoration reserves (aFRR and mFRR), at country and EU level. From the results, we observe that the potential is highest for the provision of aFRR, followed by mFRR and FCR. Specifically, the aFRR technical potential is 32 GW — 4 times the aFRR contracted in 2019 in the EU; of this, 98% is CHP capacity and 2% is P2H. In 2050, the capacity available for balancing only slightly decreases; by then, CHP still supplies 84% of the capacity, against 16% of P2H. Overall, this study highlights the lack of bottom-up data on capacities feeding DHs and the diversity of DHs in terms of size and composition. This hinders a comprehensive analysis; thus, only a case-by-case analysis can estimate the actual potential. Still, this study shows the large unused potential of DHs to provide balancing services.

Keywords: District heating, Balancing markets, CHP, power-to-heat, flexibility, frequency restoration

Georg Brandstätter is a Research Engineer at the Austrian Institute of Technology.

Efficient area of operation planning for free-floating electric car sharing systems

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Free-floating car sharing systems provide a convenient and flexible mode of transportation and enable the efficient utilization of vehicles (and thus, space) within cities. Electric vehicles are particularly suitable, since the distances driven are usually well within the range of currently available cars. To ensure both high quality of service and level of customer satisfaction, the system's area of operation must be well-covered by electric vehicles to ensure that users can quickly find a nearby car whenever they need one. Since electric vehicles are still rather costly, servicing a large area can quickly become prohibitively expensive. Thus, the operational area needs to be carefully designed to ensure that the best possible coverage with a given fleet is achieved. We present a case study for a Viennese electric car sharing system where we optimize future expansion strategies. For that, we derive a demand forecast from a national mobility survey, and use a \todoo{mixed} integer linear programming model for planning the area of operation. The goal is to cover the expected demand as well as possible. Results show that the model is highly efficient and flexible to adapt to different requirements.

Keywords: electric vehicles, car sharing

Leif Gustavsson is Professor of building technology at Linnaeus University. His main research is linked to sustainable development, especially building construction, renewable energy, forestry, and the interaction between these fields. He has authored or co-authored over 300 papers and research reports.

A lifecycle comparison of primary energy use and climate impact of biofuel and electric cars

Leif Gustavsson, Roger Sathre, Linnaeus University, Sweden

Leif Gustavsson (presenter) leif.gustavsson@lnu.se

We compare the primary energy use and climate impact of passenger cars. We analyze battery electricity cars (BEV) using standalone bioelectricity as well as with integration of wind electricity. We analyze internal combustion cars (ICV) using biomethanol, and as a reference fossil gasoline. All pathways are with and without CCS. We compare the biomass feedstock use from forest residues, primary energy use, biogenic and fossil CO2 emission, and cumulative radiative forcing of each pathway. The functional unit is 15,000 kilometers of annual travel in a medium car during 15 years. We consider manufacture and operation of cars and conduct a robust sensitivity analysis and a scale-up scenario analysis for Sweden. The BEV have strongly lower climate impacts, than ICV. Primary energy use and climate impact are lowest when wind and biomass electricity is used to power BEV. The highest climate impact occurs when methanol is used, followed by gasoline. The climate impact of bioelectricity or wind and bioelectriciy pathways with CCS is about equal, resulting in some global cooling while gasoline and biomethanol with CCS are nearly equal and quite significant after 100 years, giving global warming. Regardless of energy pathway, smaller cars have consistently lower climate impact than larger cars. We suggest that accelerating the current trend toward vehicle electrification and scaling up renewable electricity generation is a wise strategy for climate-adapted passenger car transport.

Keywords: passenger cars, biomethanol, battery electric vehicles, climate change, woody biomass, BECCS

Sajjad Haider received his BS in Electrical Engineering in 2016, and his MSc in 2020. Currently, he is working as a PhD researcher and candidate at TU Dresden. His research interests lie in investigating the impact of electric vehicles on low voltage networks.

A novel, decentralized spatial pricing model for peer-to-peer electricity distribution to consumers and electric vehicles

Sajjad Haider, TU Dresden.

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Current electricity pricing models take into account costs of generation, transmission, emissions and a fixed cost of distribution based on time of day and type of primary source. However, the authors postulate that increasing fast charging for EVs will lead to increased overloading and voltage drops observed in networks at the low voltage level. To this end, the authors propose a novel method that encourages reactive power injection to minimize voltage drops and active power injection to minimize cable loading by using a decentralized, demand-side optimized algorithm. This model allows for peer-to-peer power delivery, incentivised using pricing factors, encouraging local optimization-based solutions to network overloading. These pricing factors allow islanding in the network, as a means of improving grid resilience, and allow optimal EV charging and discharging based on network requirements. Incentivised peer-to-peer transactions are then recorded in a decentralized blockchain, with energy supply serving as the transactional commodity for both fixed consumers and generators (houses) and mobile consumers and generators (EVs). The mathematical model, as well as the impact of such a decentralized network compared to a business-as-usual network will be presented accordingly.

Keywords: electricity, grid, electric vehicles, optimization

Kertu Lepiksaar is a PhD student, whose research topic is related to district heating and energy system's coherence.

Centralised power-to-heat units as flexible consumers in the power grid

Kertu Lepiksaar, Anna Volkova, Tallinn University of Technology; Kiur Kalme, Elering AS

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The total electricity consumption capacity in Estonia may increase significantly due to the electrification of the heating sector. This trend is a good opportunity to increase the flexibility of heat production by integrating non-fuel renewable energy sources into the heating sector and increasing heat production efficiency, but it also places an additional burden on the power grid. As for Estonia, the country currently generates less electricity than it consumes, with approximately 45% of electricity having been imported in 2020. This is due to the closure of oil shale-based electricity generation facilities and the volatility of the growing wind energy sector. Integration of centralised power-to-heat solutions (including electric boilers and large heat pumps) into district heating networks can increase the flexibility of power grids, considering the high thermal inertia of district heating networks. This means that shutting down the power-to-heat unit for a short time will not cause any particular problems for the consumers of the district heating network. In terms of the power grid, power-to-heat units can be viewed as consumers with flexible load and can be managed in accordance with the needs of the network, depending on the generation needs.

This study investigates how power-to-heat unit regulation affects the district heating sector. In addition, the maximum possible amplitude of the regulated power will be determined in terms of time and capacity.

Keywords: district heating, power grid, flexibility, power to heat

Oliver Ruhnau is a PhD Candidate and Research Associate at the Hertie School in Berlin. His research is on the economics of flexible electricity demand in the context of variable renewable energy sources.

How flexible electricity demand stabilizes wind and solar market values: The case of hydrogen electrolyzers

Oliver Ruhnau, Hertie School, Berlin

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Wind and solar energy are often expected to fall victim to their own success: the higher their share in electricity production, the more their revenue in electricity markets (their "market value") declines. While the market value may converge to zero in conventional power systems, this study argues that "green" hydrogen production can effectively and permanently halt the decline by adding electricity demand in low-price hours. To support this argument, I further develop the merit order model and use price duration curves to include flexible hydrogen electrolysis and to derive an analytical formula for the minimum market value of renewables in the long-term market equilibrium. I quantify this hydrogen-induced minimum market value for a wide range of parameters using Monte Carlo simulations and complement these simplistic estimates with results from a more detailed numerical electricity market model. I find that—due to flexible hydrogen production alone—market values of renewables across Europe will likely stabilize in the range of their projected levelized costs in 2050. Other types of flexible electricity demand may further increase renewable market values, which has profound implications. Market-based renewables may hence be within reach.

Keywords: Renewable energy, hydrogen electrolysis, electricity market, electricity economics, integrated energy system, flexible electricity demand

Kasper T. Therkildsen holds a Ph.d. from the Niels Bohr Institute at the University of Copenhagen with extensive experience developing and implementing new technology. He currently holds a position as the Head of Technology at Green Hydrogen Systems.

Large scale deployment of modular pressurised alkaline electrolysers

Kasper T. Therkildsen, Green Hydrogen Systems

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Modularity is a key parameter is a key factor for the large-scale deployment of electrolysis as envisioned in both the EU Hydrogen Strategy and national Hydrogen Strategies This talk focuses on the development of a novel multi-MW-range alkaline electrolyser platform with factory assembled and pre-tested modules allowing rapid on-site installation capable of reaching low CAPEX levels. A multi-MW module fitting into a 40-foot container will be demonstrated in a large-scale industrial Power-to-X project capable of replicating across Europe with associated green growth and job creation benefits. Electricity can be supplied from both on-site renewables or grid connection and the utilisation of waste heat can also been utilised in order to bring the total energy efficiency above 90%. Electrolysis plants can also provide grid balancing services in order to reduce the cost of hydrogen.

Keywords: Hydrogen, electrolysis, green hydrogen

Prof. **Andra Blumberga** is an expert with large experience in system dynamics in different projects and research domains. She has more than 25 years of professional experience in fields of buildign energy efficiency, ventilation systems, energy, and environmental policies.

Spatial analyses of smart energy system implementation trough system dynamics and GIS modelling

Andra Blumberga, Ieva Pakere, Armands Grāvelsiņš, Marika Kacare, Dagnija Blumberga, Riga Technical University

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Major concern in utilizing renewable energy sources, such as solar or wind, is their intermittent nature, therefore the question is whether they can be reliable energy sources to provide uninterrupted energy demand, when reaching high share of renewable energy in the system. This issue can be addressed by connecting various geographically dispersed renewable energy sources, using non-variable energy sources to provide the missing energy demand (hydroelectric, geothermal, etc.), utilize smart processes (demand-response management) to shift flexible loads in order to match the intermittent renewable energy availability, store energy for later utilization etc.

The system dynamics model coupled with a GIS platform have been used in order to perform analysis over space and time using geo-referenced information. This approach allow to analyse the whole energy system by being able to determine the best suited development scenario for each region separately, based on their resource, economic and technologic capabilities. Spatial analysis also help to address the specific energy load and grid capacity issues that may arise with increase of intermittent renewable energy, by being able to timely predict the necessary grid expansion and related costs to avoid interruption in energy supply. System dynamics model is complemented with different policies in order to evaluate their impact on renewable and local energy resource development and economic potential.

Keywords: system dynamics modelling, geographical information system, renewable energy sources, energy system flexibility

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

An open spatial optimisation model to asses economically sustainable national district heating potential

Fabrizio Fattori, Alice Dénarié, Giulia Spirito, Samuel Macchi, Marianna Pozzi, Mario Motta, Politecnico di Milano; Urban Persson, Halmstad Univeristy

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The economical sustainability of DH compared to individual heating systems depends on the cost of producing heat, transporting and distributing it. Assessing economically sustainable potential of district heating DH thus requires the ability to combine this costs, detecting the relative distance of sources and demands and the density of demand, comparing it to the alternative solution. In this work we present an open model, based on the Oemof modelling framework, which is able to take into account the possibility of connecting sources and demands on national scale level with a high spatial resolution. The model considers the investment and operating costs of production and distribution of heat in competition with the individual heating systems costs specific to each area.

The end result is the most economically viable heat supply configuration, identifying the demand shares where the most cost-effective solutions are individual systems or DH and its composition in terms of energy sources.

The model is part of the method used for the assessment of district heating potential in Italy. The latter is based on GIS maps of both energy demand, waste and renewable heat sources. Of the 114 TWh of potential demand for DH, 38 TWh are those that the optimisation suggests could be economically served by DH. The composition is mostly waste heat, 22 TWh, geothermal heat, 11 TWh and a minority of solar thermal, 2 TWh with 3TWH of natural gas CHP back up.

Keywords: DH potential, Oemof, allocation, GIS, energy system optimisation

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 urban energy simulation and spatial energy planning.

Urban Building Thermal Energy Analysis at City District Scale

Hermann Edtmayer, Lisa-Marie Fochler, Peter Nageler, Thomas Mach, Institute of Thermal Engineering, Graz University of Technology

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This conference article presents the thermal energy analysis of a city district in Graz, Austria by the use of a newly developed numerical energy system model (see figure 1). From this model, a multi-tool workflow was derived to implement a high-resolution bottom-up approach at district scale. The goal was to carry out a sensitivity analysis regarding different boundary factors as varying parameters. The thermal energy demand (heating, cooling and hot water) as well as the CO2 equivalent emissions of the existing building stock in the considered area were investigated. The developed multi-tool workflow consists of several processing steps.

1) Data input from stakeholders
2) Pre-processing into a georeferenced 3D CAD urban building information model
3) Import into central PostgreSQL data hub
4) Automated urban building modelling
5) Dynamic building energy simulation
6) Post-processing and visualisation.

The thermal energy demand was calculated in hourly mean values for each building and each varied parameter. Using the annual total in combination with CO2 emission factors the annual CO2 equivalent emissions were determined. The sensitivity of the stock area to the parameter variation regarding the annual thermal energy demand could be shown. Furthermore, the influence of different energy sources on the CO2 equivalent emissions could be examined.
The research work is part of the project ECR SmartCityGraz 2020 and funded by the government of Styria and the city of Graz.

Keywords: numerical energy system model, urban building energy simulation, sensitivity analysis, CO2 equivalent emissions

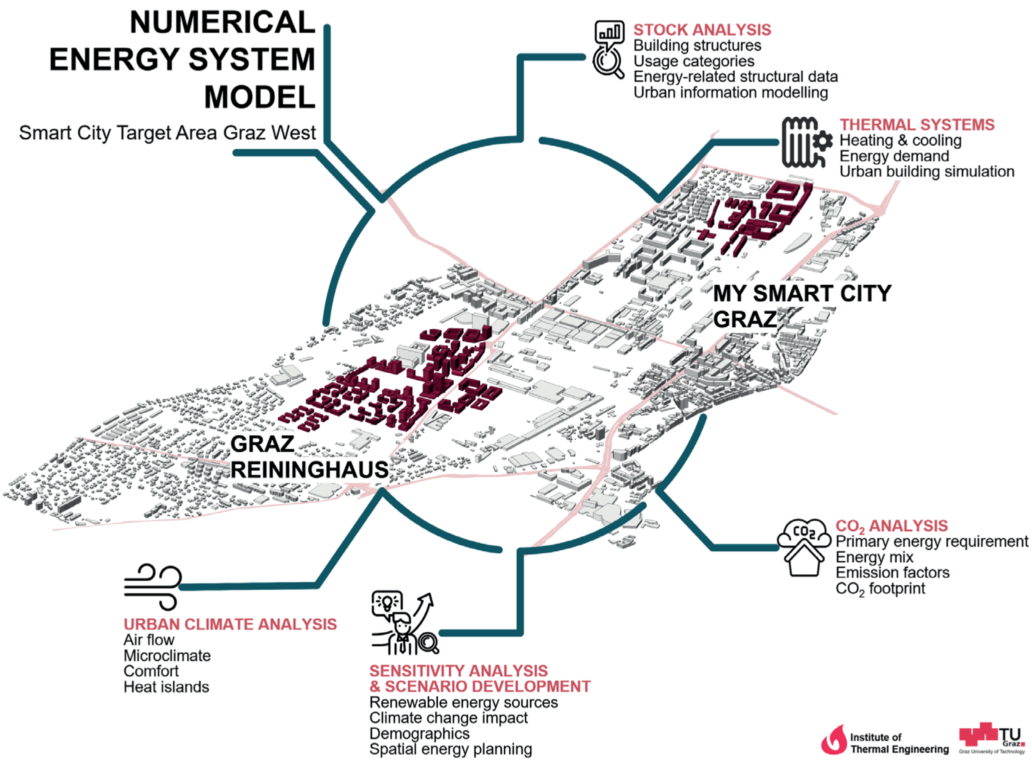

Figure 1: Numerical Energy System Model

Bernd Möller is Professor in Sustainable Energy Systems Management at Europa-Universität Flensburg, Germany. His research includes spatial analysis in energy planning. He chairs the international M.Eng. programme Energy and Environmental Management in Developing Countries at Flensburg university.

An empirical high-resolution geospatial model of future population distribution for assessing heat demands

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The future population distribution informs decisions on investment in district heating. Across Europe, demographic change has been associated with structural changes of the past. Trends towards urban or rural migration, urban sprawl or the depopulation of city centers will continue. Using gridded population data since 1990, past development is mapped using spatial disaggregation to grid cells by intensity of urban development. An empirical method proposed captures increment of population in each grid cell and relates it to the focal statistics of the cell neighbourhood. A positive population trend in populated cells leads to a future population increase and a spill over into new development areas, while a negative trend leads to lower future population. New areas are modelled based on the principles of proximity and similarity using neighbourhood trends and land cover suitability, adjusted to national and regional population trends. The result is a set of future 1-hectare population grids, which have been used to model the distribution of future heat demands. The distribution of heat demand densities, the zoning of heat supply, and the potential for individual heat pumps have been modelled. Results show that reductions of heat demands and demographic developments leave a window of opportunities to develop heating infrastructures with known technology in the present decade, after which 4th Generation District Heat technology is required to decarbonise the heating sector.

Keywords: Population modelling, heat demands, GIS

Ulrich Reiter focuses on the modelling of energy demand scenarios on different regional levels, considering political, as well techno-economic parameters. He holds both, a master's degree in environmental engineering and a doctorate in the field of energy economics from ETH Zurich.

Decarbonizing the Swiss energy demand from buildings

Ulrich Reiter, TEP Energy, Switzerland

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To achieve the Swiss net zero target by 2050, the heating and cooling sector must be decarbonized. In our study, we analyse 3 scenarios differentiated in policy framework parameters and the uptake of district heating networks. Using a GIS-based building stock model, we calculate the heating demand on building level, including GIS information for renewable sources for the period until 2050.
Based on the heating demand of each building, we derive the potentials for local and district heating networks based on further assumptions on maximum allowed heat distribution costs (see Figure 1). To estimate the locally available renewable heat sources, we include information on all available renewable sources, incl. restriction on on-site potentials due to e.g., noise restrictions (see Figure 2).
We calculate a heat energy demand decrease of 20% in 2050 compared to 2020, although the population is expected to increase by +22% (see Figure 3). Sufficient renewable heat energy is available to supply heating demand. However, in many cases, the heat needs to be distributed by energy grids as the building connected heat sources can only provide 50-75% of the heat demand. The remaining heat demand can be covered by heating networks. Depending on the scenario setup, the share of thermal networks differs between 5% up to 42%, scenario dependent. There is a limited window of opportunity for targeting higher shares of heating networks as many heat systems will be replaced in the coming decade.

Keywords: Decarbonization heat demand, GIS analysis, district heating, local area heat networks

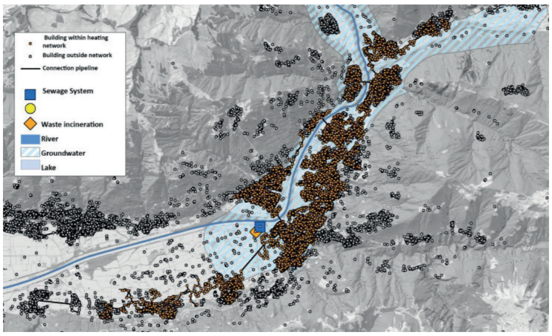

Figure 1: Potential district heating network based on heat demand, distribution cost and available heat sources

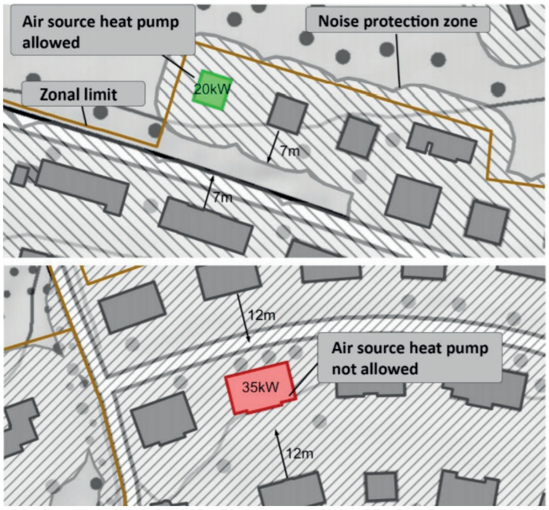

Figure 2: Boundary conditions for the allowance of air source heat pumps (noise levels, distance to neighbouring buildings and heat demand).

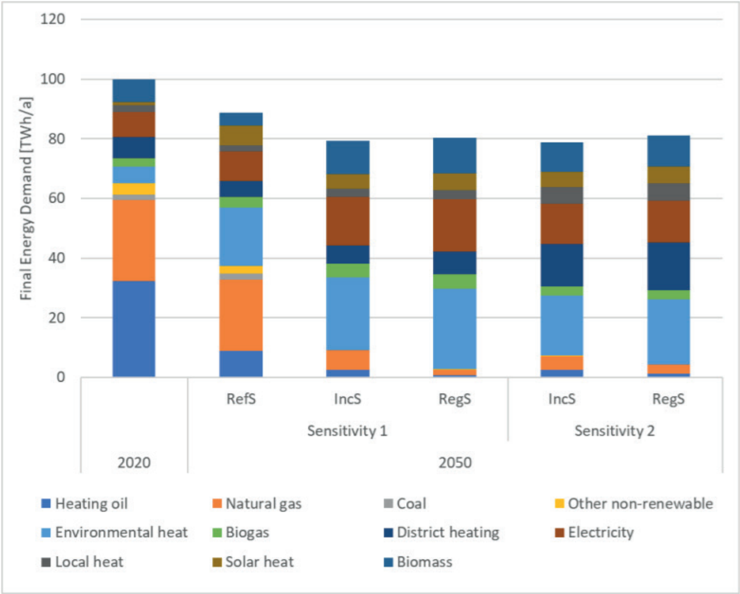

Figure 3: Final energy heat demand for Switzerland in all demand sectors in 2050 per scenario and energy carrier. In Sensitivity2, the support measures and boundary conditions are more favourable for district heat and local area networks in terms of allowed costs and implementation speed of new networks.

Luis Sánchez-García is a spanish civil engineer with a profound interest on district heating and the key role this technology can play in the decarbonization of Europe's heat supply and the improvement of the continent's energy independence

A Closer Look at the Effective Width for District Heating Systems

Luis Sánchez-García, Erik Möllerström, Helge Averfalk, Urban Persson, Sven Werner; School of Business, Innovation and Sustainability, Halmstad University, 301 18 Halmstad, Sweden

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District heating is an important technology for decarbonizing the heating supply in urban areas since it enables the recovery of waste heat that would otherwise be wasted and the cost-effective utilization of renewable heat. Nonetheless, the current general extent of these systems in Europe is very low, hence the need for simple methods and parameters to estimate their cost and feasibility on a large scale. One of these cost parameters is the Effective Width, which enables a first order approximation of the total pipe length in a given area. This concept, in conjunction with the average pipe diameter in the area, permits the determination of the network's capital cost. However, previous research of Effective Width has relied on a small set of cases and has not contemplated service pipes. Therefore, there is need for a closer look and a deeper understanding of the underlying phenomena that influences this parameter. This study has analysed several Scandinavian District Heating Systems in detail and provides new evidence on the relation between Effective Width and the urban environment for both distribution and service pipes.

Keywords: Effective Width, Plot Ratio, Distribution Capital Cost, Heat Density; District Heating, GIS

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

Assessment of the influence of demographics, refurbishment and the climate on the heat demand in district heating planning

Abdulraheem Salaymeh, HAWK University of Applied Sciences and Arts

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Since heating and cooling in buildings and industry accounts for half of the EU's final energy use, this sector has been recognised as a priority field to achieve the EU's ambition to transition into a clean economy by 2050. Therefore, information on the energy quality of the building stock forms the basis for the development of energy concepts such as district heating. Since this information is generally not publicly accessible, the heat demand mapping is performed in thermal atlases based on Open Data. Most of these atlases do not take into account important statistical and technical parameters. This article examines how and to what extent these parameters can influence the estimated heat demand by analysing the influence of demographic developments, by considering the energy-efficient refurbishment measures already implemented, and by showing the dependence on the climatic conditions at the respective area. The results show that the rising demand for heating due to the increase in the housing space per person is compensated by a negative population development. A particularly strong influence on the heat demand can be recorded when taking into account energy-efficient refurbishment already carried out. These can reduce the heat demand by up to 40 %, which in turn reduces the profitability of a district heating network by approx. 25 % under otherwise identical conditions.

Keywords: District heating, heat demand, housing space, energy refurbishment progress, climate factor

Dario Dall'Ara graduated with a Master's in Building Engineering. He is currently working as a junior research fellow in the Energy Department, in the framework of the EIT Climate-KIC funded Merezzate+ project. His area of focus is energy modelling, specifically 4GDH and de-centralised solar thermal.

Solar energy in low temperature district heating: monitoring and simulation of an innovative district in Milan

Dario Dall'Ara, Alice Dénarié, Rossano Scoccia, Giulia Spirito, Mario Motta, Politecnico di Milano.

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This study focuses on the analysis of a new DH network in Milan, which feeds 22 new buildings with low temperature heating systems, in the framework of the EIT Climate-KIC funded Merezzate + project. The single flat substations allow an important reduction of temperatures in the DH network (65-30°C) compared to the current city ones (110-65°C). The purpose of this study is the creation of a dynamic energy model to simulate the entire DH to evaluate the conversion to 4GDH of the local subnetwork and to assess future integration of distributed solar thermal on buildings roofs.

The TRNSYS network model is validated using the real monitoring data provided by the system operator with an average error about 2%. The model is then used to simulate the solar integration in two configurations: a simple solar thermal user supply using DH as back up and an alternative configuration with higher solar fraction using DH as a storage for solar energy. The solar DH is studied with today's configuration and subsequently with the future implementation of 4th generation DH. The results of the preliminary configuration proof that the decentralised solar system can save the 8% of primary energy in high temperature configuration and 12% with the future low temperature configuration. Instead, the alternative configuration can cover more than 50% of heating energy needs. The analysis shows the benefits and improvement margins of the integration of renewable sources in 4th DH generation.

Keywords: District heating, low temperature, solar thermal, sustainability, energy efficiency, dynamic simulation, TRNSYS.

Patrick Geiger is a scientific employee at Steinbeis Research Institute Solites and responsible for the RES-DHC project.

RES-DHC - Transformation of existing urban district heating and cooling systems from fossil to renewable energy sources

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RES-DHC stands for a wider introduction of Renewable Energy Sources (RES) in the District Heating and Cooling (DHC) sector. The RES-DHC project addresses the manifold market uptake challenges related to the transformation of DHC systems to higher shares of RES. In particular it aims at the development of solutions and instruments which support policy and sector stakeholders in over-fulfilling Art. 24 of RED II, requiring a yearly increase of RES in DHC by 1%. The main objective of the RES-DHC project is to support the transformation of existing urban DHC systems to RES in six participating regions and thereby to derive technical and organizational solutions for such processes. This is reached with two key approaches: A vertical pillar of the project is a close-to-market implementation process of concrete actions and measures by regional stakeholder consortia in the six regions (in DE, AT, IT, PL, FR, CH). The phases of this implementation process are 1) strategy and action planning based on local stakeholder consultation 2) an implementation phase starting already at an early stage including capacity building, legal framework improvements, market support, and triggering investments in RES DHC. A key horizontal beam of the project is to organize and give transnational support to the regional stakeholder consortia. This support is provided by an international team of expert partners with specific and complementary competences and coordinated by Danish experts.

Keywords: Renewable Energy Sources, District Heating and Cooling, Energy Transition, Sector Coupling, Market Uptake, Capacity Building, Business Models, Financing, Consumer, Policy, RED, SECAP

Eduard Latõšov is assistant professor in research group of Smart District Heating systems in the Department of Energy Technology, Tallinn University of Technology. He is one of the leading experts in the field of district heating in Estonia.

CO2 emission intensity of the Estonian district heating sector

Eduard Latõšov, Anna Volkova, Tallinn University of Technology; Siim Umbleja Estonian Power and Heat Association;

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The widespread use of district heating (DH) in Estonia provides the most efficient opportunity at the national level to achieve the goals of increasing primary energy efficiency, increasing the share of renewable energy sources, and reducing CO2 emissions. All previous calculations of the CO2 emission intensity of Estonia's DH were conducted only on the basis of statistics published by Eurostat and Statistics Estonia. To improve the accuracy of the initial data and to obtain results for specific DH networks, the actual operational data of the main DH networks in Estonia for 2020 was collected. Calculations are performed using the power bonus method and the calorific allocation or energy method. Particular attention is paid to CO2 emission factors for different fuels and energy inputs in DH systems. One of the key issues discussed is the definition of waste heat and the applicability of specific CO2 emission factors. The results of calculating CO2 emission factors based on actual operating data of existing networks are compared with the results of calculations based on statistics. The revised and refined steps for calculating DH CO2 emission factors presented are intended to be used by members of the Estonian Power and Heat Association. The general calculation approach will allow for transparent benchmarking of Estonian DH systems. It can also be used to inform DH consumers about the CO2 emission intensity and sustainability of specific DH networks and DH sector as a whole.

Keywords: carbon emission factor, CO2 emissions, district heating, waste heat, CHP

Aleksandr Ledvanov is an engineer, whose research topic is related to district cooling and energy system's coherence.

Free cooling and district heating supply usage for Tallinn district cooling production

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District cooling in Estonia is rapidly developing. First district cooling networks and plants were established, but usage of Baltic Sea water as a large-scale source for free cooling was not yet implemented. Due to the low temperatures of the water in the Baltic Sea (throughout the whole year), free cooling has enormous potential as a cooling energy source. Current research investigates the possibilities of free cooling usage for the 100 MW Tallinn district cooling network. Additional capacities for the cooling energy supply will be performed using the excess heat of existing biomass and waste incineration CHP plants. This study investigates the temperatures of water at different places, the installation of feed supply pipelines (in the area of big ship traffic), needed installations, impact for the environment and production curves for the whole city district cooling network. Due to the fact the district cooling is at the beginning phase, connection of new and existing buildings will be analyzed taking into account the idea to utilize the big amount of free cooling source.

Keywords: district cooling, free cooling, district heating

Mihai-Rareș Sandu graduated as valedictorian of Power Engineering Faculty, University Politehnica of Bucharest currently working as Research Engineer in the Energy Generation and Use department of the faculty and Research Assistant in the WEDISTRICT project.

Analysis and optimisation of a renewable energy hybrid system operation

Mihai-Rareș Sandu, Constantin Ionescu, Roxana Pătrașcu, University Politehnica of Bucharest

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The main objective of this paper is to define and optimize the operating regimes of a hybrid geothermal-solar system for production and supply of thermal energy (heat, cold and domestic hot water). The analyzed system was designed and is being implemented within the European project Horizon 2020 “Smart and local reneWable Energy DISTRICT heating and cooling solutions for sustainable living” - WEDISTRICT, into a demonstrator located in the University Politehnica of Bucharest (UPB) campus. The criteria considered in optimizing the operating regimes of the entire ”thermal subsystem-electrical subsystem”, is to ensure the conditions of thermal comfort in a target building while also maximizing the delivery capacity of thermal energy, produced from renewable sources, in the local district heating network of UPB. By simulating the operation of the system as a whole, the production and consumption regimes of thermal energy and the production-consumption regimes of electricity will be, practically, harmonized, and will identify the main categories and types of factors that influence these operating regimes. The work carried out, towards the objective pursued, focuses on demonstrating the advantages and performances of new ”smart thermal networks” functionality integrated with ”smart electrical networks”. Both concepts focus on the efficient integration of renewable energy sources and the interaction between a new type of consumers, namely prosumers, both thermal and electrical.

Keywords: hybrid system, thermal energy production and distribution, renewable energy, simulation, working regimes

Peter Verboven builds and coordinates the innovation network of Condugo. He built his expertise on smart energy over the past fifteen years, mostly through building projects and launching business organisations that have, all throughout Europe, become key players in the sector.

R-ACEs: fRamework for Actual Cooperation on Energy on Sites and Parks

Agata van Oosten-Siedlecka, Institute for Sustainable Process Technology; Peter Verboven, Condugo; Alessandro Provaggi, Euro Heat and Power; Sergio Pinotti, Spinergy; Carmen Disanto; Lombardy Energy Cleantech Cluster; Paul Robbrecht, POM; Kristine Jung, ESCI

Peter Verboven (presenter)

The potential for heat and cold exchange has been widely recognized across Europe. However, this has been underexploited due to a series of barriers to the development of low carbon industrial parks. Currently the European industry represents 50% of all cooling and heating demand in Europe, yet only 16% comes from renewables.

But how can European industrial parks reduce their CO2 emissions, waste, and material consumption? The project R-ACES aims to create Eco-regions where heat and cold are exchanged and smart energy management systems are incorporated. The vision of the project is to support industrial parks in becoming Eco-regions able to reduce greenhouse gas emissions by at least 10%. This has been reached in Belgium, Denmark and Italy by exchanging surplus energy and making extensive use of renewables.

Each region is centred on an (eco-) industrial park or (eco-) business park, linked to its surroundings by a 4th or 5th generation district heating/cooling network. With R-ACEs, we have been able to pave the way for an effective exchange of energy between European companies and stakeholders, fostering the creation of EcoRegions that aim to reduce drastically energy consumption, promoting the transition to a circular economy model and energy cooperation.

Keywords: Energy Cooperation, Industrial Symbiosis, Europe, Energy communities, District Heating and Cooling network, Industrial parks, Energy managers, Circular Economy, Smart Energy system, Eco-regions

Vladimir Vidović is a PhD student in University of Zagreb researching the potentials of floating solar panels. He is also working on project COASTENERGY – dealing with blue energy potentials. He has a master's in mechanical engineering.

Solving barriers for effective utilization of Seawater Heat Pumps for heating and cooling in the Adriatic region

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Space heating and cooling demand equals or even surpasses electricity demand in some parts of EU. Since the sector of generation of heat today is dominated by the fossil fuels in the Adriatic region, big changes are needed for energy transition towards a sustainable low carbon future. In Adriatic region air to air heat pumps are often used due to high cooling demand. This in combination with high ratio of renewable energy sources in electricity grid gives much lower emissions of greenhouse gasses. Still to get the best results we need to aim for more efficient heat pumps – with higher coefficient of performance (COP), which can be best achieved with heat pumps using seawater, especially in coastal areas. Best results are obtained for the case with low-temperature heating, which can be a barrier for the older and inefficient buildings. Thermal energy of the seawater is underexploited in the Mediterranean region, but many projects are developing these solutions. Opportunity for this technology are the new-built hotels that need heating and cooling throughout the whole year with large demand and can achieve significant savings and high level of comfort. In the COASTENERGY project, the potentials of blue energy are analyzed with specific focus on thermal energy of the sea and the resulting impact on carbon footprint. The project assessment also deals with wave energy that has lower potentials in small, closed seas, like the northern parts of the Adriatic Sea.

Keywords: Seawater heat pumps, COP, Space heating and cooling, COASTENRGY project, Adriatic Sea

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

Validity assessment of the waste heat integration into a district heating system: Case of the city of Riga

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Jelena Ziemele (presenter) jelena.ziemele@lu.lv

Reaching 100 climate neutral cities by 2030 is the ambition that determines decarbonization strategy at these cities for energy sector including district heating system (DHS). Huge amount of waste heat is diffused within the urban environment giving floor for considering the potential integration of this heat into the DHS.
The aim of the research is to provide a decision support tool that allows to assess, whether integration of waste heat into the DHS is always valid and reasonable from economic, energetic, and environmental perspective. The assessment is made considering the fundamental differences of DHSs' generations up to 5GDHS.
The system dynamics modelling approach is used to build the tool that simulates the non-linear and dynamic nature of the energy sector. Mid- (2030), and long-term (2050) scenarios are assessed for sustainable transition of DHS towards climate neutrality. Two different approaches are used to assess the potential heat amount: (1) quantification of the existing waste heat for recovery, and (2) estimation of the energy generated in the potential future plants based on renewable energy. Environmental assessment includes allocation of greenhouse gas emissions. The research also discusses whether the waste heat is always carbon neutral. The Riga city is selected as the case study, as it has committed to become climate-neutral by 2030, while its DHS still operates in the 2&3GDHS modes and no waste heat integration projects have been implemented.

Keywords: Waste heat, system dynamics, multi-criteria analysis, sustainable transition, decarbonization, 4th generation district heating, circular economy

Ralf-Roman Schmidt is a senior research engineer and is working at the AIT since June 2009, where he is responsible for the development and management of national and international projects in the field of district heating and integrated energy systems.

Integrated District Heating and Cooling Systems: Overview of the results of the international cooperation project IEA DHC Annex TS3

Dennis Cronbach, Fraunhofer-Institut für Energiewirtschaft und Energiesystemtechnik IEE; Anton Inakiev, NTU Nottingham Trent University; Anna Kallert, Fraunhofer-Institut für Energie-wirtschaft und Energiesystemtechnik IEE; Daniel Muschick, BEST – Bioenergy and Sustainable Technologies GmbH; Ralf-Roman Schmidt, AIT Austrian Institute of Technology GmbH; Peter Sorknæs, Aalborg University; Inger-Lise Svensson, RISE Research Institutes of Sweden; Edmund Widl, AIT Austrian Institute of Technology GmbH

Ralf-Roman Schmidt (presenter) Ralf-Roman.Schmidt@ait.ac.at

District heating and cooling (DHC) systems traditionally have strong links to electricity and gas networks via combined heat and power (CHP) processes. However, the role of CHP plants will change due to a growing competition for renewable fuels and an increasing share of renewable electricity production. Consequently, other heat sources will be needed. Heat pumps will play a major role, but also power-to-gas processes can contribute via recovering its waste heat, thus creating different coupling points between the DHC, electricity and gas system. By an optimized planning and operation of locally available coupling points a “hybrid energy network” (HEN) can be created.

The international cooperation project IEA DHC Annex TS3 analyses the potentials and challenges of HEN from the perspective of the DHC system. The IEA DHC Annex TS3 provides a holistic approach for designing and operating HEN. The IEA DHC Annex TS3 will connect existing national and international projects and thus benefit from interdisciplinary experience and exchange. This contribution will present an overview of the result of the IEA DHC Annex TS3 including:

- Analyses of available technologies and synergies / application areas on a national level.
- An overview of international case studies including simulation scenarios.
- An assessment of the different methodological approaches and tools.
- Recommendation on suitable business models, market design and regulations.

Keywords: District heating and cooling, hybrid energy networks, sector coupling, integrated design and planning

Peter Sorknæs is part of the Sustainable Energy Planning Research Group at Aalborg University, where he works with energy markets for energy systems based on variable renewable electricity, and hourly cross-sectoral energy system modelling of energy systems of different geographical scales.

Energy system synergies of hybrid energy network technologies

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World-wide increasing levels of variable renewable energy sources are being installed into energy systems. The variability of these sources sets new demands for the operation and management of energy systems as to best integrate these sources. Increased intercoupling between energy sectors has shown to be important for allowing a resource- and cost-efficient integration of these sources. Especially district heating and cooling networks have shown to allow for such low-cost integration. Such coupling in a local context is referred to as hybrid energy networks, being an optimized connection of local energy networks via locally available coupling points, such as heat pumps, electrolyses processes, and gas turbines. In this work the aim is to identify applicable technologies and synergy potentials and under what conditions these can be applied. This includes an assessment of coupling points, storages, and other relevant technologies. The goal of the work is to identify key technologies and when these should be applied. This is done using different energy system scenarios for two countries, which allows for analyzing potential differences under different energy system setups. The work will list recommendations for synergies applicable in different countries presented through a matrix of technologies with a focus on integration of district heating and cooling networks with other types of energy networks. The work is part of the IEA DHC Annex TS3 Hybrid Energy Networks.

Keywords: Hybrid Energy Networks, Energy system analyses, EnergyPLAN

Edmund Widl works at the Austrian Institute of Technology. His main focus is the analysis and design of multi-domain energy systems, especially hybrid distribution grids. A substantial part of his work is dedicated to the development of new tools for simulation-based assessments of such systems.

Categorization of tools and methods for modeling and simulating hybrid energy systems

Edmund Widl, AIT Austrian Institute of Technology

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Sector coupling is expected to play a key role in the decarbonization of the energy system, by enabling the integration of decentralized renewable energy sources and unlocking hitherto unused synergies between generation, storage and consumption. Within this context, a transition towards hybrid energy networks (HENs), which effectively couple power, heating/cooling and gas grids, is a necessary requirement to implement sector coupling on a large scale. However, this transition poses practical challenges, because the traditional domain-specific approaches struggle to cover all aspects of HENs. Methods and tools for conceptualization, system planning and design, assessment/optimization of system operation as well as on-line analysis and fault detection exist for all involved domains, but their adaption or extension beyond the domain they were originally intended for is still a matter of research and development. Therefore, this work presents and systematically categorizes innovative methods and tools for modeling and simulating HENs. Based on this analysis, specific application areas are identified that are either relevant for stakeholders today or where a relevance is foreseeable. The identified application areas are categorized in terms of objectives, requirements for the methods and tools as well as expected results. The aim is to provide a guideline for early adopters to understand which tools and methods best fit the requirements of their specific applications.

Keywords: hybrid energy networks, modeling, simulation, methods, tools, categorization

Dr. **Anton Ianakiev**'s research is in Smart Heat Networks, in the development of hybrid and low temperature district heating system with distributed energy storage to reduce transmission heat loses and load variations and incorporate renewable sources of heat.

Hybrid Energy Networks: - Demo Case studies

Anton Ianakiev, Nottingham Trent University

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One of the main barriers for development of new big district heating systems is the substantial investment required and the general lack fossil-free high temperature heat sources. More practical as well as effective solution is to decentralise the heat networks and to utilise new technologies to provide heat from alternative sources. At present there is insufficient electricity generation to supply all electric domestic heat. The gas grid delivers more than twice the energy of the electricity grid. At the same time sustainable "green" sources of electricity are volatile, seasonal and depends on environmental conditions. This means electricity need to be generated locally and stored in an appropriate way to maximise the economic efficiency. Hybrid decentralised heating systems represent an excellent opportunity to move away from fossil fuel sources. The future of district heating is green economy at scale – the introduction of decentralised hybrid heat local networks, integrating renewable based electrical and heat networks, supplying heat to between 10 to 100 houses, which is suitable for both urban and rural solutions.

The paper presents different Demo cases of Hybrid Energy systems: Nottingham (UK), Neuburg and Bamberg (Germany) and Innsbruck (Austria).

Keywords: Hybrid Energy systems, Local heating networks, District heating, Sustainable energy systems

After studying aerospace engineering at the University of Dresden, **Dennis Cronbach** worked at a company developing an analysis tool based on the method of finite elements for several years. He started to work at Fraunhofer IEE in 2018, where he developed the open source simulation tool pandapipes.

On business models and the regulatory framework of hybrid grids

Inger-Lise Svensson, Research Institute of Sweden; Dennis Cronbach, Fraunhofer IEE

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Some European countries, which have been leading the expansion of renewable energy systems (RES) for many years, now struggle to keep up the rate of newly, installed RES plants. One reason might be a growing resistance among residents against new RES plants like wind parks. But there are also many countries reducing subsidies, which supported RES integration for decades. Without this support, wind power plants have to compete with conventional power plants on the electricity market, which is often not feasible assuming the current regulatory framework, which was historically tailored around one specific energy sector only. To make sure that RES are more independent from subsidies and have better chances on the markets, European stakeholders need to invent new strategies. Coupling of different energy sectors plays a key role. However, a tighter coupling of different energy sectors makes it necessary to extend and improve the regulatory framework. It also introduces the prosumer as a new energy market actor, who not only consumes energy, but may actively take part in energy trading.Against this background, we summarize the results of projects in different European countries, which have created new business strategies aiming at a more integrated energy market or identified regulatory barriers. Additionally, parallels between the projects and hence the countries are drawn and recommendations for future developments given.

Keywords: regulatory boundary conditions, business models, hybrid grids, taxes, energy communities

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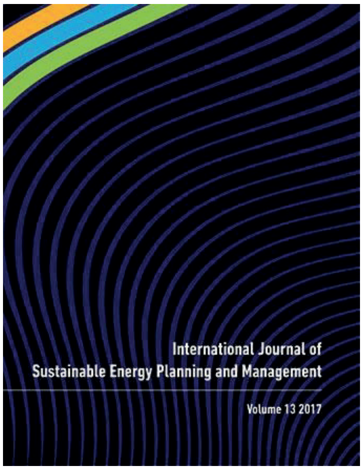

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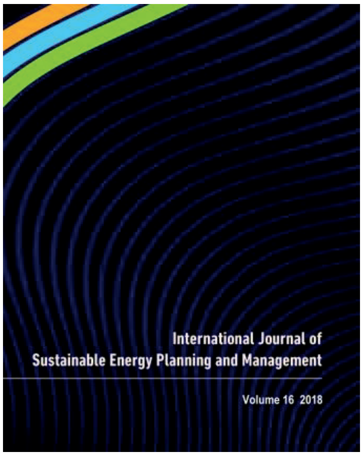

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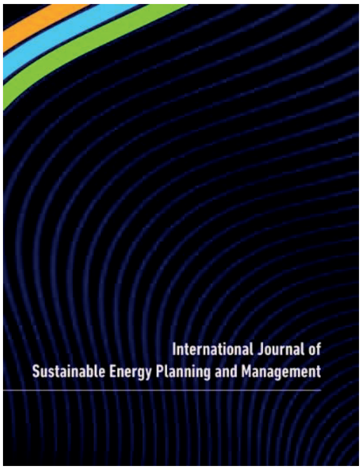

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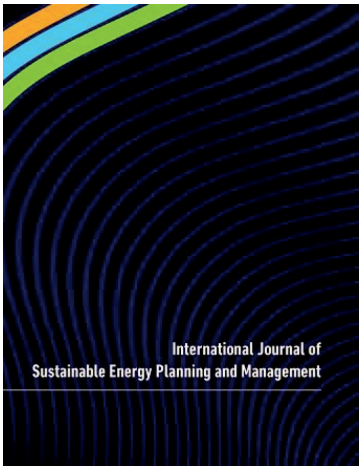

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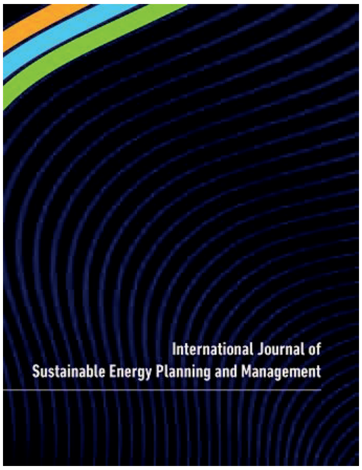

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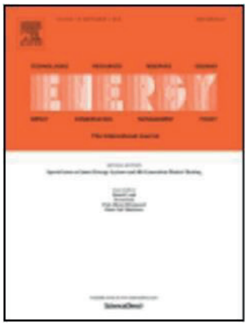
Special issue on Smart Energy Systems and 4th Generation District Heating
Selected papers from the 1st International Conference on Smart Energy Systems and 4th Generation District Heating

Edited by Henrik Lund, Neven Duic, Poul Alberg Østergaard and Brian Vad Mathiesen



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Selected papers from the 2nd International Conference on Smart Energy Systems and 4th Generation District Heating

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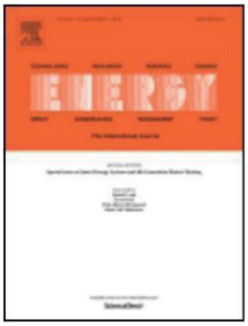

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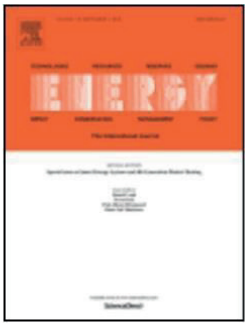

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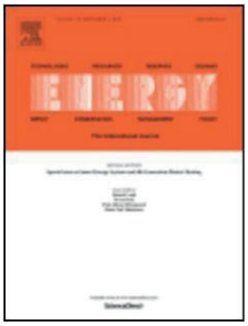

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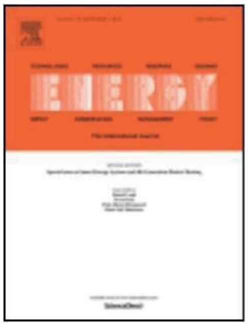

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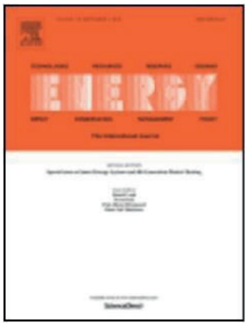

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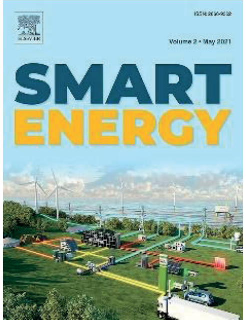

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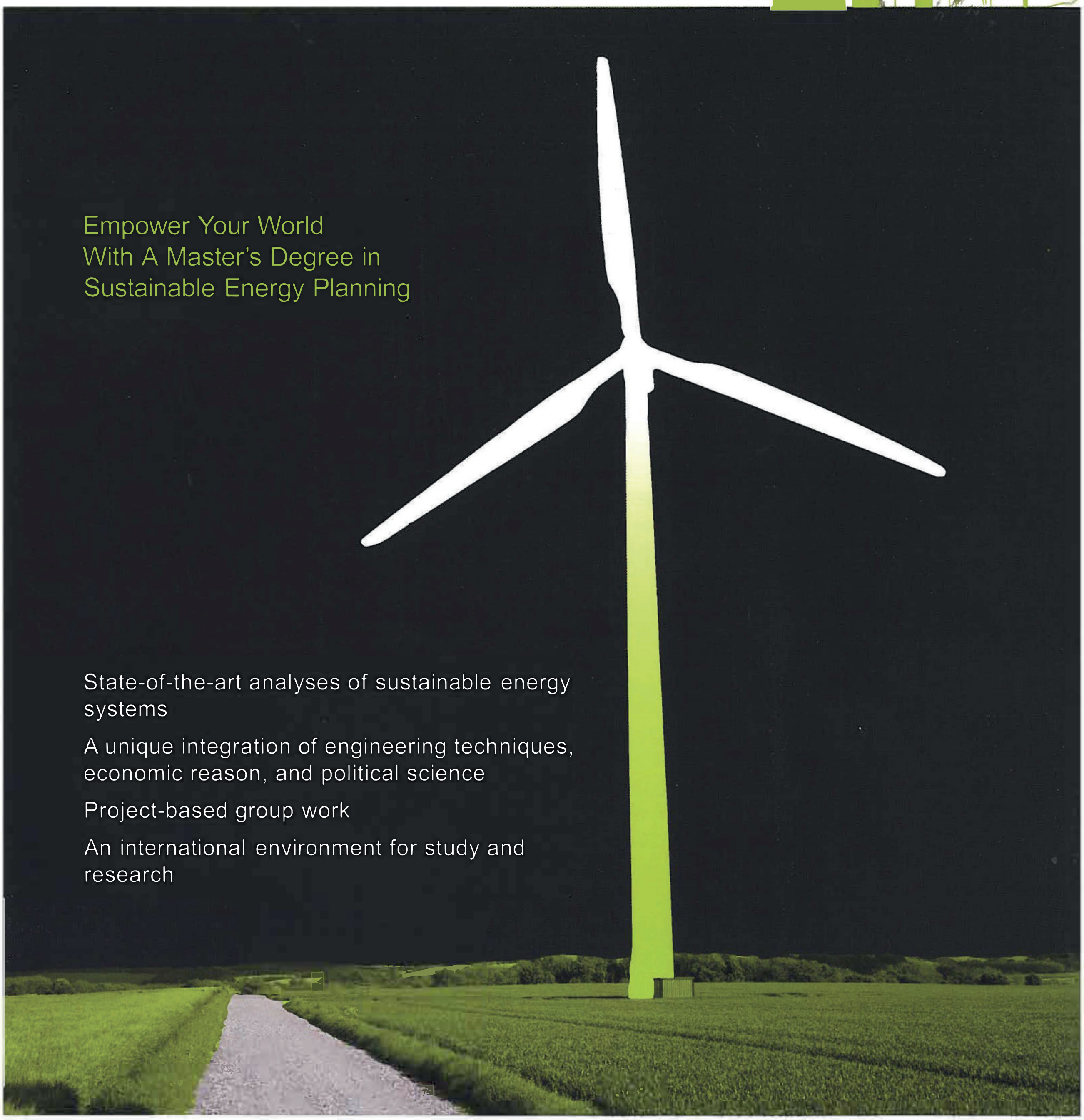

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