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DIGITALISATION
Choosing AI for Sustainable Heating: A Lithuanian Town's Journey with Digital Twin Technology

RENEWABLE ENERGIES
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DHC NETWORKS
Short Comparison of District Heating Development Potential in Germany and France

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Make or Break the European Green Deal

2024 is no ordinary year. In June, citizens will elect the next Members of the European Parliament and determine the political direction of the next European Commission. Speculation is rife as to the priorities of this next mandate, but most experts foresee a conservative push, which could slow or even halt the pursuit of Europe's climate ambitions. This is quite bad news, as the EU finalises its impact assessment on a new CO_2 emissions reduction target for 2040.

Politically, one should recognise that the economic crisis and de-industrialisation of Europe is taking centre stage, and that the appetite for new initiatives is limited, with Member States already struggling to implement the extensive measures of the Fitfor55 package. At the same time and despite progress made, the EU remains structurally dependent on fossil fuels, and in particular natural gas. Gas consumption in the residential sector grew by 50% since 1990. The de-fossilisation of Europe's largest energy consumer, heating and cooling, is still lagging behind.

To maintain momentum, the next Energy or Climate Commissioner must play it smart and focus on targeted actions with the highest impact. It reads a bit self-serving, but what about a "green heating and cooling act"?

From 2025, heating and cooling plans will be mandatory for cities above 45,000 citizens. This will enable a systematic assessment of the potential of heat networks at local level. However, we need the right tools to carry out this "heat revolution". A European Heat Fund, a framework for waste heat recovery, a geothermal strategy and even the long-awaited heat pump action plan could be essential building blocks to accelerate the deployment of new renewable and climate-neutral heat projects.

It's not as if we're running out of clean, renewable heat sources: the potential in Europe is about 2,000 TWh per year, more than the total heat demand forecasted for 2050! And in the midst of a climate and energy security crisis, it does seem like we have no heat to waste!

Aurélie Beauvais
Managing Director of Euroheat & Power, Brussels/Belgium

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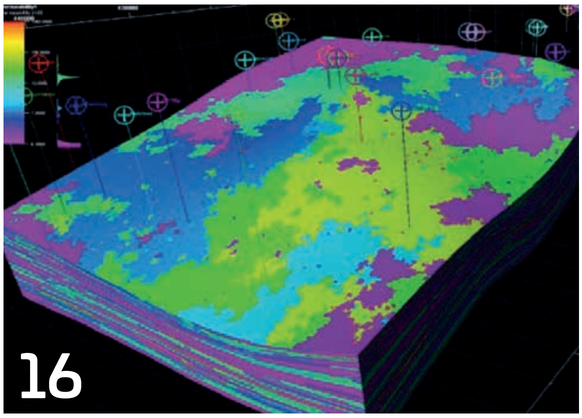

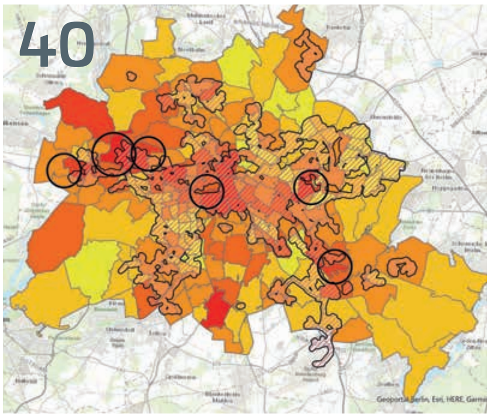

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Study: DHC Is a Top Solution to Reduce Fossil Imports

A ground-breaking study from the University of Aalborg shows that a goal of providing 20% of the EU heat demand with district heating by 2030 (compared with 13% today), would save 24 billion m^3 of gas, corresponding to 32% of EU's Russian gas imports in 2022. Euroheat & Power urges policy makers to support the modernisation and construction of new district heating and cooling systems, as a critical tool to phase-in fossil-free heat sources in buildings, and strengthen Europe's energy security.

With 41,3% shares of renewables and climate-neutral heat sources, district heating and cooling systems emerge as one of Europe's top solutions to decarbonise space heating and hot water supply in buildings and industry. The sector represents 31% of EU energy demand, with over 75% coming from fossil fuels.

The study from Aalborg University, reveals that expanding district heating and cooling networks to supply 20% of the EU heat demand would save 24 billion m^3 of gas by 2030. Gas savings are achieved with the phase-in of clean and renewable heat sources in existing and new networks (15 billion m^3), and the expansion and modernisation of existing district heating networks (6 billion m^3).

In a set of policy recommendations, Euroheat & Power called for a paradigm shift in the implementation of building renovation policies. Local heating and cooling plans must be instrumental to define building performance criteria and design appropriate clean heat incentives, to ensure that nearby renewable and waste sources are always considered. The sector also calls for the introduction of de-risking schemes for clean and renewable heat projects, as well as an urgent simplification of state aid approval procedures.

Aurélie Beauvais, Managing Director of Euroheat & Power said: "The next decade must be the one of heating and cooling decarbonisation, it has become a climate and energy security imperative. The Fit-for55' package established a clear pathway to 100% renewable and climate-neutral district heating and cooling networks by 2050, but we still need the right framework and tools to engage this massive transformation. A total of €144 billion must be invested in EU district heating and cooling networks by 2030".

Brian Vad Mathiesen, Associate professor at Aalborg university added: "District heating and cooling is Europe's next 'key enabling technology' for a cleaner and more resilient energy system. Not only does it harness clean heat sources that could theoretically cover half of the EU's current heat demand, but it is also a key solution for energy system integration. It's hard to understand why REPower EU hasn't given more support to the deployment of this technology, which has proved its worth in decarbonising heat in many countries."

www.euroheat.org

Recommendations on Financing Energy Efficiency Measures

A new Commission Recommendation on financing measures for energy efficiency has been published by the European Commission, as required under Article 30 of the new Energy Efficiency Directive (EU) 2023/1791 (EED recast), which recently entered into force. The recommendation relates to how best to use national energy efficiency funds, financial and technical support, with the objective to support Member States with the transposition and implementation of this article, which sets out key provisions to facilitate investments in energy efficiency. The text explains the amended requirements and illustrates how the objectives of the new Directive could be achieved as regards financing. The aim is to contribute to a uniform understanding of the legislation across Member States as they prepare their transposition measures.

As public finance alone (including funds from the EU budget) will not be sufficient to meet the required investment needs to achieve the new 2030 energy efficiency goals, the majority of financial support will need to come from the private sector. Therefore, Article 30 strengthens the legal and policy framework for energy efficiency financing, with the aim of increasing the cost-effectiveness of public budget support and attracting more private investment.

Article 30 EED thus incentivises the need to deploy adequate financial and technical support for energy efficiency measures, develop targeted policy measures enabling the mobilisation of private investments in energy efficiency, and promote innovative financing mechanisms and private financial products for energy efficiency. Moreover, it places an emphasis on the cooperation between the European Commission, Member States and financial institutions.

www.europa.eu

19 Organisations Call to Publish Heat Pump Action Plan Straight Away

A coalition of 19 organisations, including industry associations, NGOs, consumer groups, and think tanks issued an urgent call to European Commission President von der Leyen. The unexpected delay in publishing the Heat Pump Action Plan, originally set for the first quarter of 2024 and now postponed until after the EU elections, threatens Europe's energy transition, they warn.

With heating and cooling contributing to 38% of Europe's CO_2 emissions, heat pumps will play a critical role in achieving climate neutrality and, therefore, in shaping the net-zero economy – leading to jobs and investments.

Jozefien Vanbecelaere, Head of EU Affairs at the European Heat Pump Association said: "The heat pump sector needs more stable policies to boost the shift from fossil fuels and energy imports to clean heat and energy independence. Pushing back the Plan that can deliver is a mistake."

Many of the signatory organisations contributed to an 'accelerator' document, outlining strategies to expedite heat pump rollout, which was presented to EU Energy Commissioner Simson in June 2023, and to the European Commission's public consultation on the plan.

Large heat pumps combined with heating and cooling networks allow the harvesting of untapped renewable heating resources such as geothermal, solar thermal, and recovered heat from urban environments. Delaying the publication of the Heat Pump Action Plan – despite significant progress and the pressing need to revitalise slowing heat pump sales – risks breaking momentum and undermines long-term policy clarity necessary to reassure consumers, the sector, and all segments of society.

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€2.17 Billion to Modernise Energy Systems

Under the Modernisation Fund, the EU has disbursed €2.17 billion to help modernise the energy systems in nine Member States through 19 selected projects. These investments will help to reduce greenhouse gas emissions in energy, industry and transport, and improve energy efficiency. They are funded by revenues from the EU Emissions Trading System (EU ETS). The Modernisation Fund has now disbursed a total of €9.68 billion of EU ETS revenues since its launch in 2021.

Czechia will receive €1.848 billion to achieve a higher energy standard for public buildings and convert of coal to gas in district heating. Poland will get €221 million for high efficiency cogeneration in district heating and industry and power grids for future electric car charging stations.

www.europa.eu

Guidebook for the Digitalisation of District Heating

What should be taken into account when digitising existing and new district heating systems? Answers are provided in a guidebook created by Fraunhofer Institute for Energy Economics and Energy System Technology IEE together with international research partners.

The Annex TS4 project, "Digitalization of District Heating and Cooling: Optimised Operation and Maintenance of District Heating and Cooling Systems via Digital Process Management", was carried out from 2020 to 2023 within the framework of the International Energy Agency's District Heating and Cooling Technology Collaboration Program. 63 experts from 11 countries worked together on this essential technology for decarbonising the thermal energy system. With growing complexity or the demand for system flexibility and a renewable heat supply infrastructure and operation systems have to be adapted for future demands. On the other hand, integration of the different sectors is an important issue, and this means integration of solutions at network level as well as at operation level.

The "Guidebook for the Digitalisation of District Heating: Transforming Heat Networks for a Sustainable Future" was created as part of the Annex TS4 project. The report provides background material and current knowledge on the digitalisation of district heating systems.

The material gathered and summarised in this guidebook exhibits that digitalisation is an essential enabling technology for increasing the flexibility and efficiency of district heating and cooling systems and facilitating the wider integration of renewable and waste energy for the decarbonisation of the energy supply. The experts show how digitalisation options can be realised in district heating. They demonstrate technological, legal and economic sides. The guidebook can be found at www.iea-dhc.org.

www.iee.fraunhofer.de

Winners and jury of the 8th Global District Energy Climate Awards Source: Euroheat & Power

8th Global District Energy Climate Awards Recognise Innovative District Energy Solutions

In collaboration with the International Energy Agency (IEA) and the IEA Technology Collaboration Programme on District Heating and Cooling (IEA DHC), the UN Environment Program, and organisations of the District Energy sector – Euroheat & Power, IDEA and APUEA – an unique initiative was formed with the Global District Energy Climate Awards to celebrate success and collective attainment in the DHC sector. The Ceremony of the 8th edition of these Awards was held during the Euroheat & Power Summit on 14-15 November 2023 in Brussels, Belgium.

The finalists, hailing from diverse cities and communities worldwide, represented local district energy pioneers, showcasing leadership in delivering clean and sustainable energy solutions. The Euroheat & Power Summit in Brussels served as a dynamic platform, attracting over 230 professionals from global organisations, industry leaders, policymakers and civil society representatives. While the European DHC sector is ready to accelerate the transition towards renewable and clean heat sources, capturing the attention of a broad audience and decisionmakers remains challenging. The Global District Energy Climate Awards (GDECA) are an effective way to highlight the achievements and diverse approaches of successful District Energy stories.

"We extend our heartfelt gratitude to the projects that dedicated their time to apply, presenting innovative and sustainable district energy solutions," said Robin Wiltshire, Chair GDECA and Chair IEA DHC. "A special acknowledgment goes to our esteemed winners, whose groundbreaking district heating and cooling concepts and projects have set new benchmarks. We also express appreciation to our panel members whose rigorous evaluation of the projects ensured a fair and thorough assessment. Lastly, a sincere thank you to the Euroheat & Power team for their exceptional coordination, making this initiative and the awards ceremony possible. Together, we celebrate the triumphs and collective strides toward a sustainable and resilient future in the District Heating and Cooling sector."

Modernisation and/or Expansion

Modernisation and/or Expansion – category recognising the District Energy system that had the most positive impact in terms of effectiveness and efficiency after implementing the modernisation and/or expansion. Aspects of modernisation may be technical, managerial, or operational. Expansion can target a new area or sector. The winner is the Pons District Heating Network – Emasol Project in Pons, France.

The project consists in the installation of a solar thermal power station of 1,800 m^2 (Figure 1) with storage of 500 m^3 intended to supply in hot water the heating network of the city of Pons. Solar thermal power allows the annual production of about 1,000 MWh, 21% of the annual production of heating and more than 250 t of CO_2 emissions avoided annually. The operator of the system is Newheat since September 2021. Newheat produces and sells solar heat to the current delegate of the heating network Dalkia. The City of Pons is owner of the heating network of Pons and the first subscriber of the heating network.

"Newheat is humbled to be a Global District Energy Climate Awards winner. Our team has worked hard to complete this innovative solar thermal project, through which the city of Pons in Charente Maritime (France) has been saving money since July 2021, and even more so during the current energy crisis. The renewable heat produced by flat plat collectors installed on trackers (a world first) replaces most of the natural gas used to supplement the existing biomass heating plant, particularly during the summer months. The heating network has now a share of around 90% renewable energy. Each year, it avoids the emission of more than 250 t of CO_2 by supplying heating and domestic hot water to the network," said Nicolas Graveline, Head of International Development, Newheat.

Figure 1. A solar thermal power station of 1,800 m^2 supplies the heating network of the city of Pons
Source: Newheat

Sector Coupling

Sector Coupling – category recognising projects that demonstrate the technical integration and the synergies achieved between thermal energy systems and electricity systems. The winner is the Pit Thermal Energy Storage in Høje Taastrup, Denmark.

VEKS (municipality owned heat transmission company) and HTF (consumer owned heat distribution company) has implemented a Pit Thermal Energy Storage (PTES) in Høje Taastrup, Denmark, to provide flexibility to the electricity production system and the heat production system in Greater Copenhagen. The project was developed 2017-2018 and implemented 2019-2022. During implementation material tests were carried out and new implementation methods were developed. Size of the storage is 70,000 m^3, storage medium is water, in- and outlet capacity is 30 MW and storage content is 3,300 MWh. The project has several innovative elements, such as:

- It is the first PTES of it´s kind serving with flexibility and heated up to 90 °C constantly.
- A new business model had to be developed to integrate the storage in the heat and electricity production system in Greater Copenhagen.
- A new developed polypropylene membrane is implemented to resist higher water temperature. It is used for tightening of bottom and sides and for floating membrane under the lid. Implementation methods for membranes had to be modified further because the membrane is vulnerable to low temperatures.

- In- and outlet system and lid have innovative elements.

The storage serves four combined heat and power plants and three waste-to-energy plants. Optimisation of electricity production (sector coupling) and saved peak production result in 27.4 TJ saved fuel/a and a total CO_2-reduction of 6,200 t/a. The total investment is €10.7 million. Simple payback period is 12 years and IRR is 7.5%. The PTES is commissioned end of December 2022 and in commercial operation from 15th February 2023.

"Thank you very much for this great honour of being selected as the winner of 8th Global District Energy Climate Award 2023. VEKS and Høje Taastrup District Heating companies, are both humbled and excited that the international jury have shown us this honour. We hope the project may inspire other to build heat pit storages. Let us know if you need some advice. By projects like this we reduce our use of natural gas and other fossil fuels. In fact – a simple and effectful contribution to the green transition," said Morten Stobbe, CEO VEKS.

Emerging District Energy Market

Emerging District Energy Market – category highlighting the successful implementation of a District Energy system in a country that does not yet have an established District Energy market. The winner is the Tallaght District Heating Scheme in Dublin, Ireland.

The Tallaght District Heating Scheme (TDHS) is the first large-scale district heating network of its kind in Ireland. The scheme went live early in 2023 and operates under Heat Works, Ireland's first not-forprofit energy utility, fully-owned by South Dublin County Council. The scheme will make a significant contribution to reducing carbon emissions in the area, saving almost 1,500 t of CO_2 each year and establishing Tallaght as a leader in innovation in the area of climate change. The TDHS delivers a high level of innovation, as waste heat from the nearby Amazon data centre will supply the heat to the network. During normal operation, heat demand will be 100% covered from the data centre waste heat.

South Dublin County Council initiated this project to exemplify the environmental value and potential of district heating in Ireland. The collaboration between the council, Amazon, Fortum (the contractor) and the Dublin energy agency Codema has resulted in a low-carbon solution, optimising the potential of recyclable heat combined with innovative heat-pump technology. Heat Works intends to be an exemplar heat network business in Ireland, delivering economic, environmental and social benefits for residents and businesses. It will become a prominent part of the county's identity, supporting the local and national climate action plans by reducing its carbon footprint and helping make South Dublin a better place to live, work and visit.

"Trading as Heat Works, Ireland's first publicly owned, not-for-profit energy company, is now providing lowcarbon heat to public buildings in the area. The development of this innovative, low-carbon initiative has been led by South Dublin City Council with the assistance of its energy agency, City of Dublin Energy Management Agency, Codema. The Tallaght District Heating Network was partly funded by the European Union's Interreg NWE programme (HeatNet), Project Ireland 2040 Climate Action Fund, SEAI and through direct funding from SDCC. In the Government's Climate Action Plan 2023, the increased ambition is that Ireland will reach up to 0.8 TWh of district heating by 2025 and up to 2.7 TWh by 2030," said Admir Shala, District Heating Development Manager, Codema – Dublin's Energy Agency.

Out of the box

'Out of the box' – category recognising initiatives which do not fit in any of the other categories listed for the Global District Energy Climate Awards but show evidence of significant innovation in the District Energy sector. The winner is the Centrio Chicago District Cooling System in USA.

Centrio operates the largest carbon-free ice storage chilled-water system in the United States, providing sustainable district cooling service to nearly 53 million square feet of building space in 115 buildings across downtown Chicago, Illinois. Centrio's first central cooling plant was established in 1995. Over the past 28 years, Centrio's Chicago grew from a single central plant serving a handful of downtown customers to a district of five distribution plants interconnected by 8.5 trench-miles of piping and several satellite chiller plants. The district cooling system continues to improve and grow. In the last three years the system has grown by 13% and the major modernisation and expansion effort included the installation of the Chicago River Ultra Filtration System, Plant 2 Modernisation, and Construction of the Old Post Office Cooling Plant & Distribution.

Centrio Chicago has taken a holistic approach to reach a carbon-free cooling solution for downtown Chicago citizens and businesses by coupling climate and natural resource solutions within the district thermal cooling storage sector and electric sector as well as the water sector. As a result, the system is experiencing savings of approximately 35,000 t of Carbon each year with about 250,000,000 million gallons of water savings each year. Additionally, the Chicago operations team has successfully converted about 45% of its refrigerant inventory to an option that results in a decrease of about 400 GWP.

"Centrio is deeply honoured to accept the 2023 Global Climate District Energy Award. As an organisation dedicated to sustainability and maintaining a 99.99% reliability record, we are grateful for the recognition of our system in downtown Chicago for operational excellence, and pioneering sustainable practices in what has become North America's largest carbon-zero district cooling system. From innovative river-water cooling to thermal ice storage or 'Ice Battery', the district has evolved into a beacon of hope for a climate-resilient future. This unique system was designed to operate at night and melt during the day, reducing costs and carbon emissions and it also leverages the Chicago River for aqua-thermal heat rejection and employs proprietary technologies, saving 250,000,000 million gallons of water annually, benefiting the community and establishing higher industry standards. Thank you again for recognising our efforts in the battle against climate change. Together, we can push the boundaries for sustainable energy and truly innovate to make a difference," said Meghan Riesterer, Chief Sustainability Officer and Senior Vice President ESG & Decarbonization, Centrio.

Special jury award

The evaluation panel, while highly impressed by all submissions, recognised a standout project, due to its sound concept, high replicability potential, and the overall quality of the proposal. Therefore, the jury decided to grant a special award – Certificate of Merit to the project Hospital Severo Ochoa Waste Heat Recovery in Madrid, Spain.

An existing heating system, providing heat to seven large buildings of one of the largest hospitals in Madrid has been modernised by using low temperature waste heat from cooling towers of the hospital itself. By inserting a heat pump into the system, the waste heat can be recovered, and heat and hot water (including high temperature process water for sanitation) is provided. The waste heat recovery support the existing gas boilers and in combination with photovoltaics installed on the hospital buildings rooftops electricity for the heat pump is generated. As a result, both the waste heat and the electricity needed for the system to work, are locally available making the hospital resilient to external impact (like gas supply and price of electricity). The payback of the system has been estimated at less than two years, the primary energy savings are 3,624 MWh/a and 820 t of CO_2/a. The success of the system modernisation showcases the importance of making public buildings forerunners in the energy transition. The system solution is unique in that it recovers waste heat from cooling towers, such are common in countries with warm climate, indicating a vast replication potential.

"ASIME is characterised by a strong R&D&I component in all its projects. We are proud to be awarded in the 8th Global District Energy Climate Awards for the project installed at the Severo Ochoa Hospital in Madrid that takes advantage of residual heat through a technological development based on booster heat pumps. Thanks to this project, in 2022 it has been possible to reduce annual energy consumption of this hospital by 21% and CO_2 emissions by 70%. We believe that this award should serve as an incentive to European administrations to adapt this type of measures to the majority of tertiary buildings in Europe, where the consumption of general services can represent up to 70% of the energy cost," said Jesús Marín, Business Development Director in Brussels, Grupo Empresarial Electromédico.

How to be part of the Global District Energy Climate Awards?

The GDECA are awarded every two years. Next round of applications will open in 2025. The Awards coordinator, Euroheat & Power, is currently accepting expressions of interest to host the 2025 ceremony in conjunction with a major District Energy-related event.
Since this is an international initiative, the awards invite participation from diverse corners of the globe, including the Latin American market and the Asia-Pacific region. Eligible applicants include owners, operators, communities and organisations served by a District Energy system. Finalists will be selected from those who best articulate their ambition and aspirations for District Energy performance improvements.
www.districtenergyaward.org

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Optimal Extension Planning of District Heating Networks by Phased Investment

How can the upfront costs for district heating network development be lowered? Phased investment is a promising solution, but designing heating networks with phased investment requires careful consideration. In his master thesis, Mathieu Peeters showed how an automated design strategy, utilising numerical optimisation, can generate cost-effective phased district heating network designs.

Modern district heating networks are seen as an important contributor to decarbonise the heating sector in a reliable, cost-efficient way, because they allow to integrate renewable and waste heat. Moreover, local pollution from gas or oil boilers can be avoided. The main challenge of building new and expanding old district heating networks is the high upfront investment cost for the pipes and roadworks. Due to the high initial investment costs, it is challenging to find the private and public capital, and political support to further exploit the potential of district heating. In addition, large heating network concepts ranging over boundaries of municipalities might be delayed by long permitting processes.

One promising approach to alleviate both obstacles is phased investment planning: Instead of building the network at once, the network is expanded in multiple investment phases. As such, the network owner can already generate revenue before investing in further extensions, reducing the upfront investment costs and the overall project risk. Today, different mathematical (optimisation) frameworks are used to design the network topology and the pipe diameters in an economically optimal way. An overview of different approaches can be found in Wack et al. [1]. However, a physics-based optimisation framework that optimises the topology, pipe sizes, and operation of heating networks considering multiple investments phases did not exist up until recently. In Mathieu Peeter's student thesis [2], an approach was developed which aims to close this gap and enable optimal heating network designs for phased investment (Figure 1).

The approach is implemented as an extension of Pathopt [3;4], an advanced framework for the design optimisation of district heating networks. It is based on a complete heat transfer model that accurately accounts for the influence of nonlinear effects in fluid flow and heat transfer on the design. The methods used are scalable such that whole districts and/or small cities can be studied. The authors want to highlight with this article the possible benefits of leveraging phased investment on the roll out of district heating networks.

New heating network design optimisation method for phased investment

The work of this student project was part of a KU Leuven master thesis [2] and was presented at the 9th International Conference on Smart Energy Systems in September 2023 [5]. An extensive explanation of the underlying network simulation and core optimisation algorithm can be found in Wack et al. [4]. In the following, its extension to phased investment planning is described. The aim of the presented method is to minimise the total discounted costs of the network (Capex and Opex), built in multiple phases, by optimising the network topology (pipe placement), the pipe diameters, and the network operation. In case of phased investment, two or more network sections are simultaneously optimised.

In the developed method, an optimisation algorithm is thus set up to drive down the total project costs. This cost estimate assumes the following: The heat producer unit is considered to be built at full capacity from the start, to cover the peak heat demand of the final network. Similarly, network circulation pumps are dimensioned from the start to cover the final network. Hence, all the Capex of heating and the pumps were assigned to the first investment phase. Capital costs of piping, on the other hand, need to be covered only in the phase were they are laid out. The operational costs of each period contain heat costs and pumping costs.

To account for the phases of investment, areas are predefined in which the network can be developed in each phase, such as done

Figure 1. Network topologies of the greenfield, the optimal extension and the enforced extension design. The blue pipes are built in phase 1, the yellow ones in phase 2

for a test case in Figure 2. In general, it is of course technologically possible to lay new pipes in every street in every phase. However, it is very challenging to do roadworks in the same street multiple times within few years, due to government regulations or local opposition. The initial network connections are therefore assumed to remain, meaning that no pipes or consumers are removed from earlier to later phases. Hence, the last phase contains all streets and consumers. Pipes that are constructed in earlier phases are then re-used in later phases.

Specific to this procedure is that a fully-fledged flow and thermal simulation is done for each period, to accurately capture heat and pressure losses throughout the network. Thereby, the thermal comfort satisfaction of all connected consumers and compliance with pressure limits within the network can be guaranteed. The simulations also allow to accurately determine the heat and pump-related Opex for each of the different operational phases.

Showcasing the method's potential – a test case

To demonstrate the functioning and merits of the phased investment network optimisation method, it is applied to a test case. The case aims at designing a medium-sized district heating network in Eeklo, Belgium. In total, the case has a single producer, 58 consumers, 584 streets, and 430 junctions. The street grid is considered for possible piping routes. For a first analysis, small consumers (e.g., single family houses) were neglected, leading to an overall smaller heat demand density of the region.

In Figure 2, the selection of the two phases can be seen. In the first phase, all consumers in the zone closest to the producer are connected. In the second phase, the consumers further away are added. It is assumed that the heat from the producer, a waste incineration plant, is provided at 70 °C. Considered as capital costs are the heat capacity cost, the pump installation cost and the piping cost (pipes + roadworks). Characteristic investment costs for the heat production unit and the pumps are taken equal to €1,000 /kW and €100 /kW, respectively. The pipe cost has two contributions. A fixed cost represents the cost of the roadworks needed and is set to €400 /m. A second contribution scales with the diameter and represents the physical costs of the pipe, it is set to €1,976.3 /m^2. For the operational costs of heat production and pumping, the heating and electricity costs are set to Ct1 /kWh and Ct11 /kWh, respectively. The life time of the whole project is set to 30 years and the discount rate is set to 5%. It is assumed that the second part of the network is built after five years.

The costs of greenfield design, optimal extension, and enforced extension planning

In the following, three network designs are compared. The greenfield design is the optimal network if all customers are connected right from the start. This design will be used as a reference result to assess the phased investment. The second design is the optimal phased investment design (optimal extension). The third design (enforced extension) shows what would occur if the extension was not incorporated in the initial design of the network. All three designs are given in Figure 1.

In case of the greenfield design, the full network is utilised for the longest possible time, leading to an optimal trade-off between heat losses, pressure losses, and investment costs in all years. All costs can therefore be discounted over

Figure 2. The Eeklo case, with the producer at the bottom of the figure. Consumers are the white (medium heat demand) and orange (high heat demand) dots, while the black lines represent the streets. Encircled are the two investment zones, the zone closest to the producer will be connected first

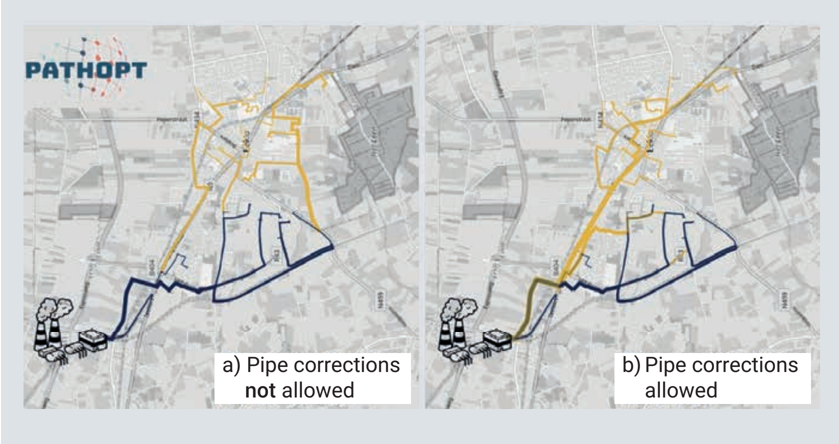

Figure 3. Enforced extension design a) without and b) with allowing for corrections of piping laid out in the first phase. When corrections are allowed, the backbone is significantly reinforced (brown pipes), with the second phase pipes (yellow) being placed in parallel to the backbone. This helps in overcoming the flow challenges

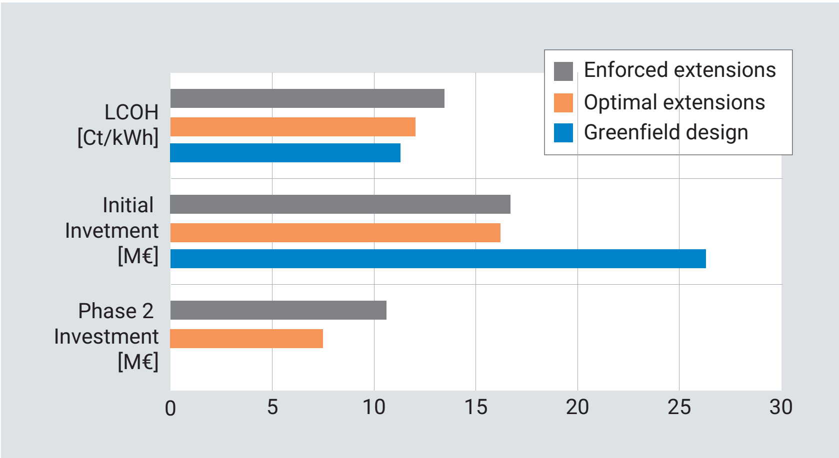

Figure 4. LCOH, initial investment and phase 2 investment of the greenfield, the optimal extension and the enforced extension design

the longest possible time, but the initial investment is higher.

For the optimal extension, there is now a trade-off to be made by the optimiser for the pipes built in the first phase: Larger pipes will have lower pressure losses in the second phase, but larger heat losses and piping cost in the first phase. As can be seen in Figure 1, a part of the backbone which connects the consumers of the second phase is already built in phase one. The topology looks similar to the one of the greenfield design in the sense that the network lay-out features a main backbone on the left hand side. Yet, the connections to the remaining consumers are now made in phase two only. Regarding the enforced design, it is obvious that the network from phase 1 is not designed for later extension. In contrast to the optimal extension, the pipes constructed in the first phase (in blue) are comparatively small. Hence, connecting a large number of consumers at a later stage leads to challenges for the flow. The optimiser therefore looks for solutions to solve this issue and chooses big pipe diameters in the network of the second phase, stemming from an aimed reduction in pressure loss. In addition, a parallel route is exploited to be able to deliver the heat to the consumers.

Given that this network is clearly suboptimal, the next step was to correct for the initial design errors. In the code this is done by allowing the placement of additional pipes in parallel to the existing pipes from the first phase. It is seen that when given this option, the optimiser decides it is indeed economically more interesting to reinforce the backbone of the network. Both network topologies (with and without allowing for corrections) can be seen in Figure 3.

To get an idea of the consequences of these different design strategies, the financial results of all three designs are summarised in Figure 4. The levelized cost of heating (LCOH), which represents the minimal sales price of the heat that would lead to a breakeven project, is higher for the optimally extended design than for the greenfield

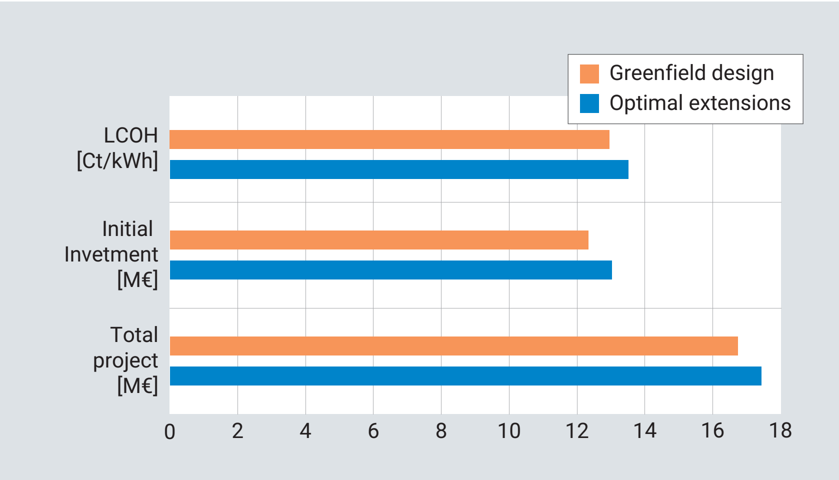

Figure 5. LCOH, initial investment and total project costs for the first phase of the optimal extension and the greenfield design

design. This is a logical consequence of the phased investment, because: Firstly, for the consumers connected in the second phase, heat is only provided for 25 years. This LCOH increase due to the reduced time of heat supply is not offset by the reduction in discounted investment cost (due to the later investment of phase 2) and the reduction in operational cost. Secondly, the tradeoff between the phases for the pressure and heat losses leads to an additional increase in costs. Nevertheless, the main goal of reducing upfront investment is clearly achieved, with an initial investment cost for the optimal extension that is significantly lower than that of the greenfield design. As such, the network owner can generate revenue before re-investing in the network. The total cost of not accounting for the extension in the initial design is 9%, or €2.9 million.

What is the cost if the optimal extension cannot be implemented?

But what if the first investment is not followed up by a second in the end? There could be many reasons for this. The approval for the second region may not have been granted, investments may have been put on hold due to a deterioration in the economic climate, or the planned expansion of the central heat source may have failed. To assess the sunk costs of the extension planning, the network optimised for optimal extension is compared to the one optimised only for the first phase. The latter corresponds to the first phase of the enforced extension design shown earlier.

The financial results are summarised in Figure 5. There is a cost penalty of 4%, or €0.7 million for the network extension planning if the extension is never implemented. These additional costs come mainly from the higher investment in the pipes. These are larger due to the expected increase in flow for additional customers. The operational costs of both networks are very similar, with larger heat losses in case of the network designed for extension that are partially offset by lower pressure losses. Comparing this to the cost of not planning for a realised extension, the benefits of an optimal extension strategy are a factor of 4 larger than the sunk costs when not implementing this planned extension. It is thus certainly worthwhile to consider extension plans from the outset when designing a network.

Conclusion and outlook

A new method for phased investment planning is introduced for the automated design of district heating networks. The approach was demonstrated on the design of a heating network in Eeklo, Belgium. The results show a significant reduction of upfront investments by splitting the construction of the network into two phases. It is shown how an informed optimal extension, planned from the outset, saves 9%, or €2.9 million over an uninformed (enforced) extension strategy. This optimal extension strategy comes at a sunk cost of 4%, or €0.7 million if the planned extension is not implemented. Hence, the cost savings of optimal future extensions are a factor 4 higher than the opportunity cost of planning a network extension but never realising it. This gives investors and policy makers much needed financial boundaries for heating network projects.

In conclusion, the presented approach lays out the foundations for a potentially very impactful tool for future phased investment design studies of district heating networks. It provides a first step towards alleviating the excessive and uncertain upfront investment, which is likely one of the main obstacles on the path to the wide implementation of district heating networks as a means of decarbonising the heat supply.

Acknowledgements

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DHC+ Student Awards

Mathieu Peeters won the runner-up prize of the DHC+ Student Awards 2023.

References

[1] Wack, Y.; Serra, S.; Baelmans, M.; Reneaume, J.-M.; Blommaert, M.: Nonlinear topology optimization of District Heating Networks: A benchmark of a mixed-integer and a density-based approach. Energy, 2023.

[2] Peeters, M.: Optimal Extension Planning of District Heating Networks by Phased Investment. Leuven: K.U.Leuven. Faculteit Ingenieurswetenschappen (Master thesis), 2023.

[3] Blommaert, M.; Wack, Y.; Baelmans, M.: An adjoint optimization approach for the topological design of large-scale district heating networks based on nonlinear models. Applied Energy, 2020.

[4] Wack, Y.; Baelmans, M.; Salenbien, R.; Blommaert, M.: Economic topology optimization of District Heating Networks using a pipe penalization approach. Energy, 2023.

[5] Lund, H.; Mathiesen, B. V.; Østergaard, P. A.; Brodersen, H. J.: Book of Abstracts: 9th International Conference on Smart Energy Systems. 2023.

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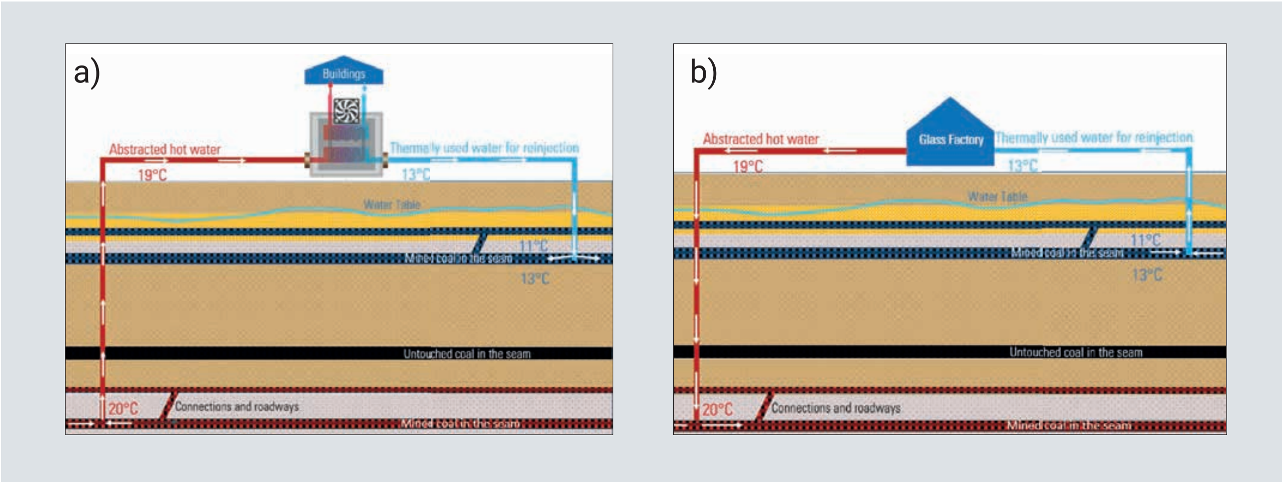


Figure 1. a) Heat recovery mode and b) heat storage mode

Minewater Utilisation as a Secondary Heat Source and Heat Store in Smart Local Energy Systems

Unlocking minewater's potential: A study delves into integrating minewater and waste-heat for smart heating and cooling, aligning with the UK's net-zero goals. It becomes a key thermal storage solution for seasonal demand variations, building on the GreenSCIES project in Barnsley.

Minewater is identified as potential thermal storage to support seasonal variations in demand. Building upon a preceding feasibility study within the GreenSCIES project in Barnsley, Yorkshire, the research explores the integration of heat, power, and mobility in a smart local energy system, utilising waste heat from a glass factory. Using minewater for heat recovery emerges as a sustainable, low-carbon solution for both heating and cooling applications, offering valuable thermal storage capabilities to address inter-seasonal demand fluctuations.

This study focuses on scrutinising subsurface variables such as flowrate, yield, mine volume, void space, and interconnectivity directly impacting the flow and thermal attributes of accessible minewater. A numerical simulation explores diverse scenarios, assessing the influence of various engineering configurations on hydraulic, geochemical, and geological parameters. The objective is to tailor designs to different demand scales, facilitating the testing of operational approaches for efficient and sustainable heat or cooling extraction, including the judicious use of thermal storage.

Minewater, possessing distinctive attributes conducive to efficient heat recovery and storage, emerges as an optimal medium for capturing and storing substantial thermal energy. Previous studies reveal that approximately 54% of the primary energy utilised in electricity supply undergoes annual wastage in the UK, with heat energy constituting the most readily dissipating form. This research assesses the viability of recuperating and storing waste heat in minewater to address inter-seasonal variations in demands in Barnsley, South Yorkshire. Historical data is scrutinised, aiding interpretation through both 2D and 3D software packages. Additionally, local mining techniques and coal mining maps are examined to estimate capacity in the project's upcoming phases.

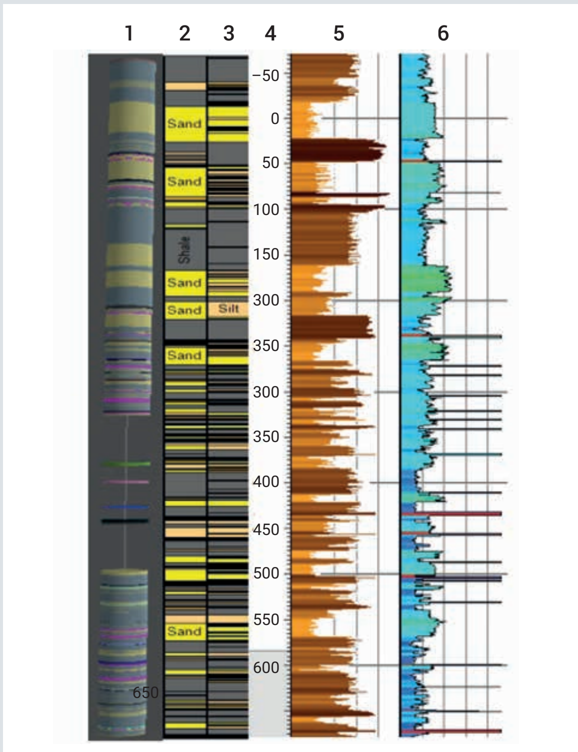
The study extends a prior feasibility assessment conducted in Barnsley, affirming the viability and economic feasibility of recovering 7 MW of heat from a glass factory while utilising abandoned mine workings for heat storage and retrieval. The initial concept envisions mine water facilitating seasonal thermal storage, serving as a backup and complement to the primary energy source, industrial waste heat. Extracting 7 MW of waste heat necessitates a substantial water volume. Flooded abandoned mines, compared to untouched subsurface formations, show relatively high permeability, offering a promising pumping rate opportunity in Barnsley. To optimise cost-effectiveness, minimising the number of wells is preferable.

Figure 1 depicts the principles of heat recovery and storage. In the heat recovery phase, minewater at elevated temperatures is pumped and circulated through a heat exchanger. Subsequently, a heat pump enhances the temperature to facilitate distribution through district heating. Conversely, in storage mode, lower-temperature water from shallow seams is drawn and circulated through a heat exchanger to absorb waste heat. This accumulated heat is then stored in a deeper seam with a higher temperature, rendering it suitable for inter-seasonal demand. Notably, cold water functions as an industrial cooling system in this scenario.

This study employs diverse data sources, including maps, historical records, logs, and pertinent research, meticulously analysed to construct a subsurface model and simulate groundwater flow behaviour. The aim is to forecast the long-term impact of various management strategies on the system. This integrative approach underscores the value of consolidating data into a unified model, accounting for historical variations between different mining techniques. Key parameters of the proposed scheme are tested using this data-driven model, exploring the likelihood of different worked seams meeting the local demand scale of recovering 7 MW of heat energy. The model, crafted through innovative software applications like BGS Groundhog and Schlumberger Petrel/Eclipse 300, will further investigate thermal response and flow behaviour, incorporating reservoir engineering techniques. The results will undergo analysis to quantify uncertainty ranges, mitigating the risk of costly test boreholes in project planning. Correlation of model outcomes with temperature measurements and flow tests holds significant value for evaluating the commercial viability of this and similar projects in Barnsley and beyond.

Functional description of the structural model

The preliminary model, executed in Groundhog 3D, facilitated the visualisation of borehole data and the creation of a simplified 3D subsurface model, enhancing comprehension of the geological structure beneath the surface. This data served as a foundation for the construction of a more intricate model in Petrel. Within this investigation, examinations and digitisation of 45 historical boreholes within the designated area were conducted. Petrel, a computational software, employs math-



Code	Name	Parent	Background
0	Sand		
1	Silt		
2	Coal		
3	Shale		
4	Sand-Silt-Clay		

Figure 2. Brierley Road borehole, well cross section data. Continuous and discrete curves; wireline data vs depth

ematical algorithms to interpret geological and geophysical data, generating both static and dynamic models for simulating reservoir behavior during fluid extraction through pumping.

Well logs, which include data from drilling and well logging operations such as gamma ray and porosity logs, are crucial for constructing a reliable 3D model. Various physical measurements yield lithological interpretation represented as continuous curves across the measurement depth. The gamma log (GR) measures the natural radioactivity of rocks and is commonly used to identify and correlate different rock formations within a well. Petrel software relies on the availability of gamma log data. In cases where such data is absent, it becomes necessary to generate a gamma log using lithological data obtained from coring. In this approach, the lithology of core samples is identified, and the gamma-ray emission properties of lithologies are determined using established values for typical lithologies. Typical log patterns from wells in similar depositional environments are utilised to create a "synthesised log" for either gamma and porosity logs. A lithology-porosity table is generated for the interpreted facies, linking BH data with log values. This table is then used to convert lithological data to porosity values. Figure 2 provides an example illustrating the assimilation of lithological data into synthesised well logs for the Brierly Road borehole at a depth of 700 m.

Column 1 exhibits lithological variations derived from BGS Groundhog model. Column 2 presents interpreted lithology, wherein data from neighbouring wells was used to fill gaps, simplifying details and integrating thin layers into thicker units. Column 3 illustrates facies logs generated using synthesised gamma logs, displaying variations consistent with log patterns associated with fluviatile depositional environment/facies. Column 4 represents depth (m), while Column 5 displays gamma logs obtained from lithological data at 0.5 m intervals. Lastly, Column 6 exhibits similarly derived porosity logs.

In Petrel, after importing the meticulously prepared well-log data, the subsequent step involves correlating the logs by establishing appropriate relationships between different rock layers. This process entails analysing the logs for common patterns and utilising stratigraphic facies. Facies, in this context, refer to rock units with analogous properties determined by the depositional environment characterising the formation, encompassing lithology, porosity, and permeability. For quality assurance, the resultant 3D model underwent a thorough comparison with regional interpretations derived from additional stratigraphic borehole data beyond the specified area of interest. Figure 3 illustrates the "Winter

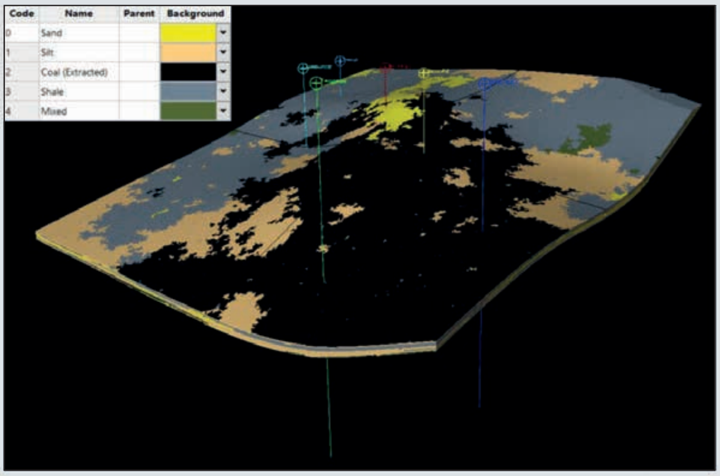


Figure 3. Model from top Winter Seam showing lithology variation (facies) model – cold source

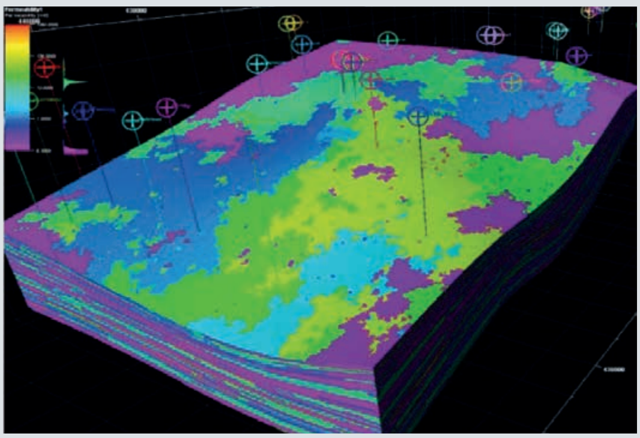


Figure 4. Permeability model, from top of the Winter Seam – cold source

Seam – Low Beamshaw" zone, the cold source, within the 3D facies model, along with the location of correlated well logs. Additionally, Figure 4 depicts the permeability model for the same zone. Permeability is a measure of how easily fluid can flow through a porous medium, such as a rock formation.

Heat demand

In the envisioned plan encompassing 7,616 residences within the Barnsley vicinity, an annual heat demand of 63,647 MWh necessitates fulfilment. Additionally, an extra 7 MW of heat is requisite to accommodate peak heat demand. This supplemental heat can be sourced by harnessing stored waste heat within disused mines. The storage of 7 MW of heat mandates a substantial water volume and void space. This heightened requirement underscores the imperative for sources situated in high-transmissivity layers, such as sandstones, faults, and abandoned mines.

For the designated heat storage reservoir in the proposed initiative (Barnsley seam), the average thickness of the seam stands at 2.5 m, with temperatures exceeding 18 °C. The documented water level affirms the presence of the shallowest flooded seam, Winter, situated at a depth of 138 m below ground level. Within this region, the Winter seam exhibits an average thickness ranging from 0.8 to 1.5 m. Figure 5 illustrates the mineworking panels in the Winter seam from an aerial perspective. The thickness of these panels, governed by factors like geological conditions, equipment specifications, and safety protocols, varies. In the UK, longwall mining panels typically range from 2 to 5 m, while room and pillar panels are generally 1.5 to 3 m thick. Considering the diverse mining practices employed since the 18th century, estimating the exact thickness of mineworking panels regardless of coal seam thickness is challenging. Therefore, the Barnsley seam's thickness is presumed to be 2.5 m, aligning with the coal seam thickness. Unlike the Winter seam, the Barnsley seam's mines are antiquated, primarily utilising the room and pillar technique. The volume of the Winter seam is computed based on 1.1 m the average local mining.

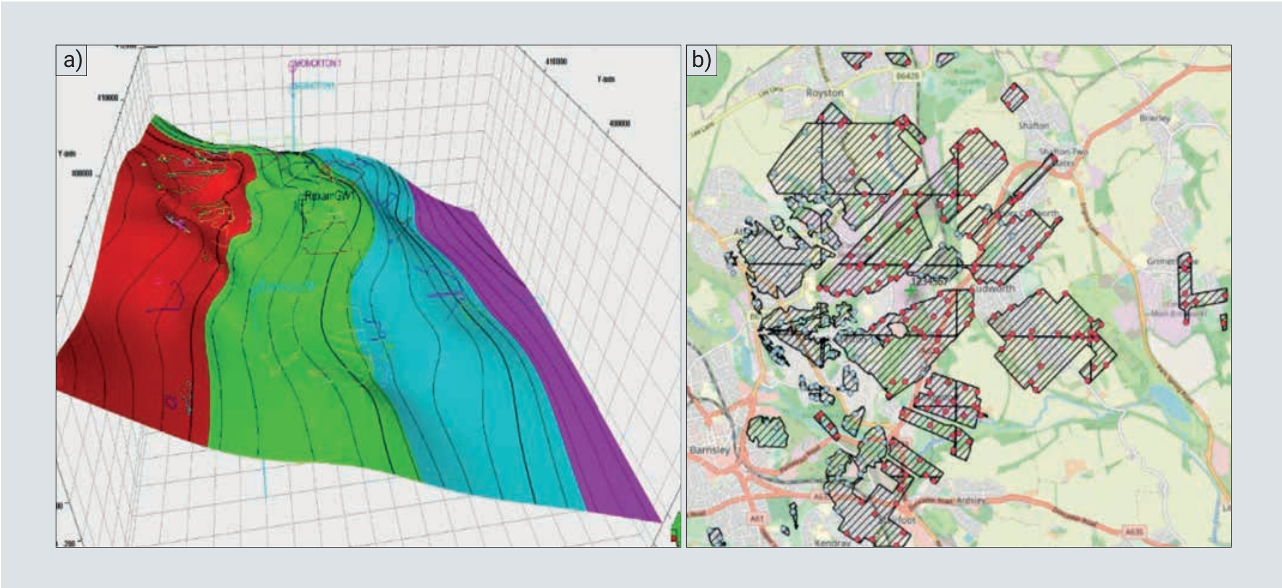


Figure 5. Mineworking map in Winter seam a) in 3D and b) from the top

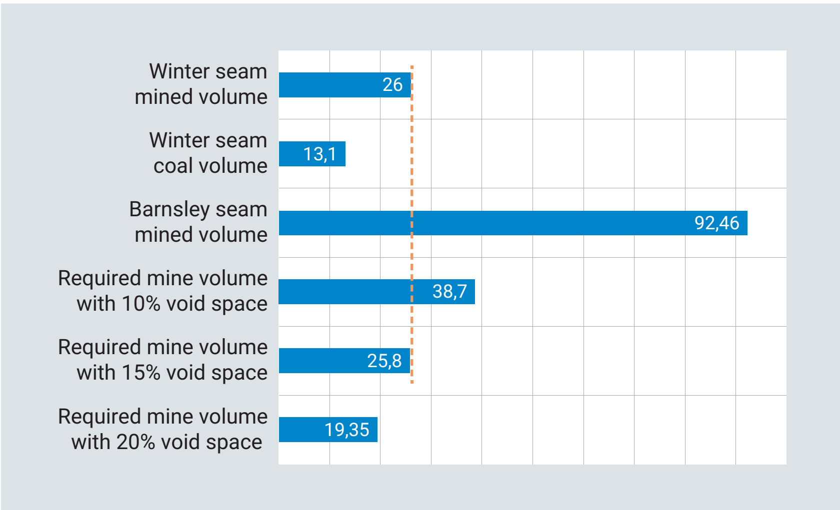


Figure 6. Available mine volume vs required mine volume in $M.m^3$ to accommodate required amount of water for $\Delta\Theta$ = 5 °C

The estimated volume of mineworking panels in the Winter seam, designated as the cold source, is approximated at 26 Mm^3. In contrast, the Barnsley seam boasts a substantially larger volume, totalling 92.5 Mm^3. Assuming the system operates 70% of the time over the 6-month storage period, a minimum void volume of 3.87 Mm^3 of water is imperative for storage in abandoned mines, assuming the extraction of 5 °C of heat during circulation. Figure 6 provides estimations of the requisite mine volume in Barnsley's seams across various parameters. A comparison is drawn between the volumes of Winter and Barnsley seams and the necessary mine volume under scenarios ranging from the worst-case situation (only 15% void volume) to the most probable condition (20% available void volume). The graphical representation illustrates that both the Barnsley and Winter seams exhibit the capacity to accommodate the necessary water volume.

This research has pioneered an innovative methodology for quantifying essential variables within various low-carbon SLES scenarios specific to Barnsley. The utilisation of mine water for energy storage not only addresses seasonal demand fluctuations but also presents a sustainable, long-term heat source. The initial study scrutinised mine water in local coal seams, revealing its capacity to sufficiently meet the heating needs of homes on a significant scale in Barnsley.

DHC+ Student Awards

Eshagh Goudarzi won the DHC+ Student Awards 2023 for "Out-of-the-box-thinking".

Eshagh Goudarzi M.Sc.,
Helen Turnell Ph.D.,
Catarina Marques Ph.D. FInstR,
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Choosing AI for Sustainable Heating: A Lithuanian Town's Journey with Digital Twin Technology

Lazdijų šiluma, a Lithuanian district heating company, has integrated Digital Twin technology into its operations. Currently, the Lazdijai district heating network operates under maximal automation, minimising human intervention within the bounds of existing technical infra-structure. The EA-SAS Digital Twin has notably reduced heat losses in the network and optimised heat production.

Lazdijai, a quaint town in Southwest Lithuania (Figure 1), is home to nearly 4,000 residents. The Lazdijai district heating company Lazdijų šiluma supplies the heat to the area using biomass boilers, operating three boiler houses: one in Lazdijai town and two in the surrounding villages. The town's primary boiler house features two moving grate biomass boilers, each with a 3 MW capacity, with a total installed capacity of 6 MW and an economizer. The district heating (DH) network spans over 6 km of pipelines. In 2022, the Lazdijai town boiler house produced 11.6 GWh of heat.

It is worth mentioning that Lazdijų šiluma operates the smallest DH network in Lithuania. „Being small-scale, with correspondingly low consumption and energy production, operational quality is very important for us. Any change in control has a substantial and noticeable impact. This is why the Digital Twin technology, enabling precise and timely control, is so advantageous for us," states Remigijus Aleksandras Viniarskas, CEO of Lazdijų šiluma.

In an era where energy efficiency and sustainability are global priorities, Lazdijai town DH network operator's decision to innovate reflects a broader trend. This step forward not only demonstrates the town's commitment to innovative energy solutions but also sets Lazdijų šiluma as an example of how local initiatives can effectively contribute to larger environmental goals.

Challenges unveiled: Why Lazdijai DH network turned to AI

Lazdijai DH network, like other third-generation district heating companies, faces industry-specific challenges. The operation of the DH network inevitably depends on numerous variables. Boiler operators usually rely on personal experience and/or a mode card when setting or changing control parameters (set points). This way of control is not sufficient for stable operation of the boiler and network. The instability in heat consumption by users, variating quality of biomass fuel, and thus the changing operating modes of the boiler, further complicate achieving consistent and efficient control. Often, achieving the required heat output is achieved at an excessively high fuel temperature. This can cause the boiler to overheat, necessitating time for cooling. In most DH companies, the temperature of a hot water supplied to the network is determined based on outdoor air temperature, without considering consumer behaviour. All these factors contribute to the growing need for a smart system capable of adapting to these circumstances and predicting heat demand.

"After hearing Energy Advice present their solution and engaging in discussions with Vytautas Siozinys, the CEO of Energy Advice, we found ourselves truly inspired. We recognised the potential for significant gains in a range of areas," states Viniarskas. "In my view, everyone is compelled to operate with high efficiency. We face legal standards and regulatory demands, which means that any advancements we make are largely attributed to savings achieved through reduced fuel consumption. This, in turn, unlocks potential for further investments and enhancements in our processes. Driven by this vision, we initiated the development of the comprehensive EA-SAS Digital

Figure 1. Lazdijai municipality, Lithuania; more: lazdijai.lt and lazdijusiluma.lt

Twin. The system meticulously models the town's boiler house, with detailed representations of the biomass boilers and economizer, and comprehensively extends to the district heating network, capturing the pipelines and the end-users."

Decoding the technology: understanding the EA-SAS Digital Twin system

A Digital Twin is a mathematical copy of a process, realised in digital format and using real-time measurement data. The first step in implementing a Digital Twin project involves inventorying: collecting and digitising data about the existing system. When developing the DH network Digital twin, this information includes significant parameters of the boiler house and network elements: specifications of boilers, pumping stations, economizers, heat points, pipelines, historical data on consumer heat consumption. All this is incorporated into the creation of the Digital Twin, which continuously collects real-time process measurement data and performs calculations in the cloud. In this way, a precise mathematical copy of the entire heat network is created, and processes are optimised through smart management. The Digital Twin's ability to analyse large data volumes in real-time becomes a significant advantage. While a person can analyse only up to three parameters at a time, the Digital Twin and AI models handle big data sets. EA-SAS Heating continuously performs real-time mass and energy balance calculations for the heat network, and EA-SAS Boiler for the biomass boiler.

For the biomass boiler, the EA-SAS Boiler Digital Twin calculates key biomass quality indicators: calorific value and moisture content in fuel, evaluates the biomass dosing process, the efficiency of the economizer, heat losses with supplied air and exhausted flue gas, and accordingly, constantly optimises system operation in real-time. Additionally, the Digital Twin provides long-term AI-based insights about boiler efficiency, smoke recirculation, grate operation, flue gas dew point and acidic dew point, heat transfer coefficient, corrosion and erosion parameters, and other indicators tailored to specific client needs. This allows for planning maintenance operations and investments to the infrastructure.

The DH Network Digital Twin collects real-time readings from heat stations and consumer smart meters, performs real-time heat-mass balance calculations, evaluates heat losses, predicts heat demand for heating and hot water supply based on meteorological forecasts and consumer consumption profiles, and accordingly sets the optimal temperature of the thermal water supplied to the network for each hour. EA-SAS Heating, besides control, can generate many additional benefits: display network parameters in a GIS view (temperature, pressure at any network location), assess mechanical stresses in the pipeline, plan heat production based on the heat production cost and electricity price, seeking the optimal balance between thermal fluid flow and temperature.

Equipment	EA-SAS Automatically Controlled Parameters	Description
Three-way valve	Temperature setpoint for the three-way valve [°C]	Optimised temperature of the hot water supplied to the city heat network to minimize heat losses in the network while maintaining technological requirements.
Primary air fans	Fans' efficiency [%]	Optimising the performance of primary, secondary, and tertiary air fans to ensure efficient fuel combustion.
Secondary air fans	Fans' efficiency [%]	
Tertiary air fans	Fans' efficiency [%]	
Flue gas draft fans	Fans' efficiency [%]	Optimising fan performance for optimal draft and combustion processes at the current boiler operation mode.
Flue gas recirculation fans	Fans' efficiency [%]	Optimising fan performance to stabilise temperatures.
Fuel feeders	Feeder pause [s]	Optimising fuel layer and grate speed for efficient fuel combustion.
Grate	I grate speed [s] II grate speed [s] III grate speed [s]	

Table 1 EA-SAS Automatically Controlled Parameters

EA-SAS implementation in Lazdijai: enhancing control

The automation level at Lazdijų šiluma has been significantly increased. Parameters automatically controlled without human intervention are listed in Table 1. All listed parameters are calculated in real-time by EA-SAS, considering the calculated calorific value of the fuel burned and the forecasted demand for thermal power. AI-calculated control commands are sent directly to the control system.

Undoubtedly, all parameters are closely related, and the created model of the boiler house and heating network is complex and com-

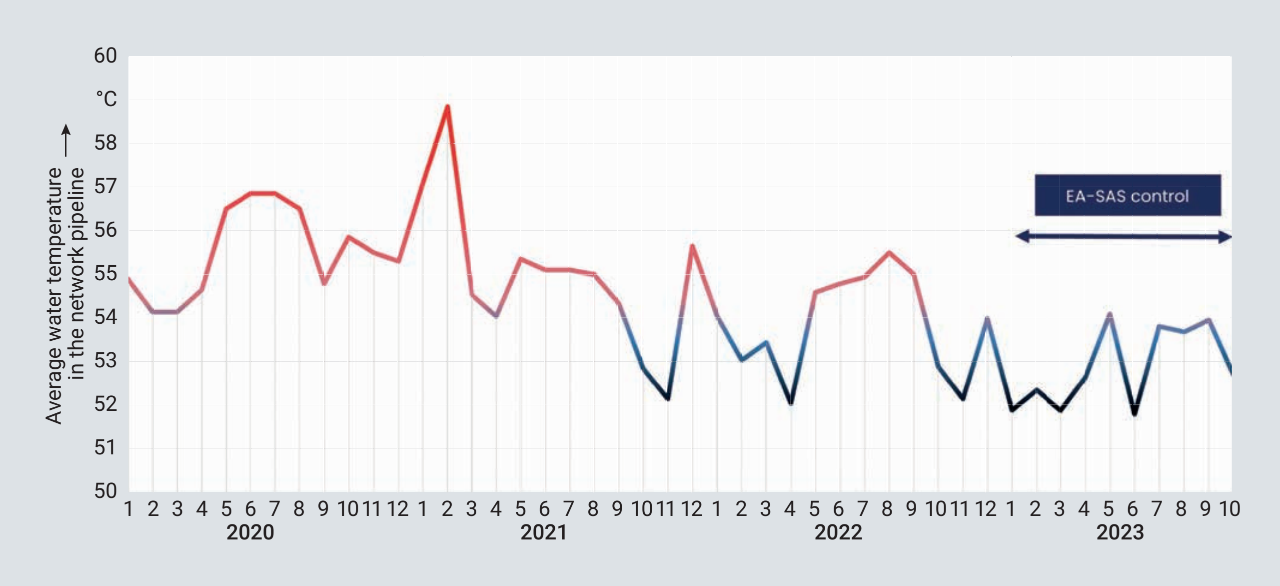

Figure 2. Average water temperature in the network pipeline

prehensive. It evaluates the influence of different components on the overall boiler house operation.

As Viniarskas noted, companies managing heat networks aim for efficiency and want to assess the quality of their operations. To evaluate the savings achieved, trends must first taken into account. Overall, the city's heat demand is decreasing due to climate warming and modernisation of buildings. Eliminating the influence of outdoor temperature using degree days, heat consumption in 2022 decreased by 8% compared to 2021. This also signaled the relevance of implementing smart control. With the optimal automatic remote control by the Digital Twin, from January to October 2023, the average temperature of the hot water supplied to the heating network reached 60 °C. Thus the average water temperature in the network pipeline decreased (Figure 2). Dynamic temperature regulation ensured compliance with technological requirements and consumer needs with lower losses in the network pipelines.

When comparing data across various years, merely examining the amount of fuel used and the heat generated is not enough. It is necessary to consider that during the analysed periods, the demand for heat and ambient air temperature varied. Also, by lowering the temperature of the supplied hot water, the network's operating mode changes: a higher flow is needed to transfer the same amount of heat. As the flow changes, so does the pattern of heat losses. Knowing that the thermal insulation properties of the network essentially remained unchanged during the periods under consideration, the impact of smart control can be assessed by eliminating these differences through a relative indicator. The summarised results are presented in Table 2.

Calculations showed that if the Digital Twin solution had been used, thermal energy production due to reduced pipeline losses would have been lower by: 20.2% (380.54 MWh) in 2020; 24.5% (511.18 MWh) in 2021;

Year	Heat sold [MWh]	Heat produced [MWh]	Heat losses [MWh]	Losses coefficient, [r.u]	Surplus consumption in accordance to reference year [%]	Surplus consumption in accordance to reference year [MWh]
2020	8,865.4	10,752.9	1,887.5	54.9	20.2	380.54
2021	11,022.3	13,105.4	2,083.1	58.0	24.5	511.18
2022	9,668.7	11,580.2	1,911.5	56.6	22.6	432.10
2023 (January-October)	6,237.9	7,596.2	1,358.3	43.8	reference year	reference year

Table 2 Smart EA-SAS Control Effect Comparing Data from 2020-2023

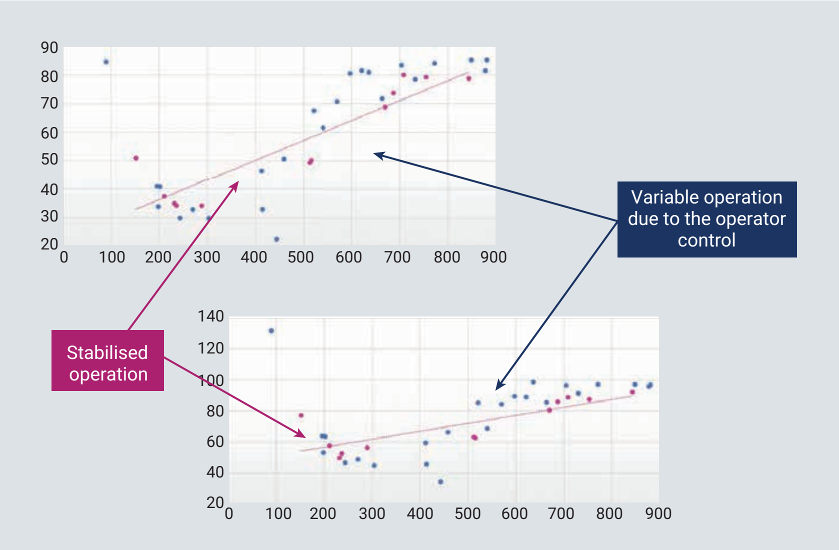

Figure 3. Stabilised operation due to the smart control

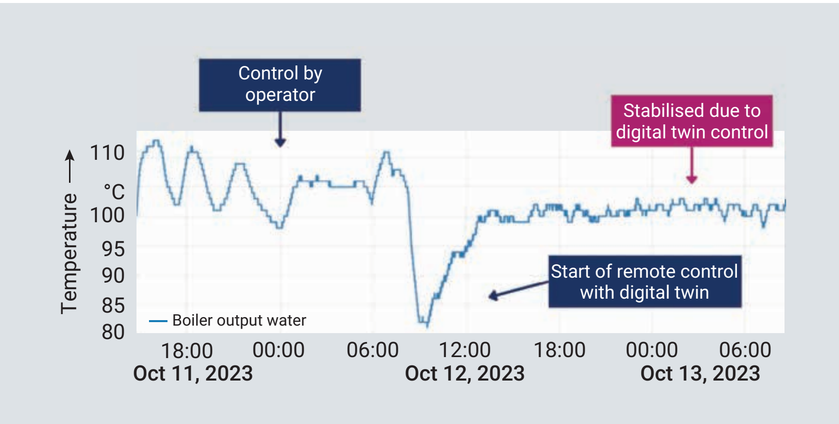

Figure 4. Temperature control transition from operator to Digital Twin

22.6% (432.1 MWh) in 2022. The effect of reduced heat losses in the network can also be illustrated by the kW/K indicator, taking into account amount of heat produced or consumed and the ambient outdoor temperature. Examining the indicators (Figure 3), it is evident that historical heat supply is variable and fluctuates with different heat demands. By applying EA-SAS smart control, the indicator is stabilised.

Boiler water output temperature is usually considered when evaluating the performance of a boiler. It is one of the main parameters that DH networks aim to stabilise. EA-SAS's Digital Twin effectively achieves this through optimal remote EA-SAS Cloud to PLC control. The technology includes Digital Twin and PID loop approach. Proactive control of the operational set points allows precise temperature control. Figure 4 illustrates the impact of such control: post-implementation, the temperature is more stable than under manual operation, which indicates reduced heat losses.

Benefits are clearly evident

At the present, the Lazdijai DH network is controlled automatically and without human intervention to the maximum extent allowed by technical capabilities. AI Digital Twin ensures that the network is continuously controlled according to the most suitable parameters at any given time. The active involvement of Ričardas Muraška, Deputy Director of Lazdijų šiluma, and Mindaugas Skripkauskas, Head of the Lazdijai Boiler House, in the developing of the Digital Twin, has led to an exceptionally accurate mathematical mode. This transition to automated control in the company was smooth and resulted in notable savngs.

"Digital Twin technology provides us with a comprehensive understanding of our system, allowing us to evaluate and optimise our operations effectively. Traceability, in my view, is a foundational aspect in our field. Employing AI solutions adds a layer of detail, thoroughness, and accuracy. When these elements are applied to achieve desired outcomes, they generate substantial benefits for both our company and, consequently, for our consumers. I encourage other district heating companies to be open to new ideas and AI-based innovations; these are the keys to enhancing quality," summarises Viniarskas, CEO of Lazdijų šiluma.

Acknowledgement

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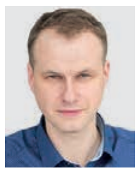


"CHP Plays a Unique Role in Participating in the Power and Heat Generation Decarbonisation"

Europe is on the path of decarbonisation. A key technology will be hydrogen-ready gas power plants. The German utility EnBW is counting on it. They have signed agreements for two combined heat and power (CHP) plants with GE Vernova. EUROHEAT&POWER spoke to Brice Raisin, Senior Executive Sales Leader Gas Power of GE Vernova, about the order, the technology and the decarbonisation potential.

EHP: *GE Vernova recently got two orders from EnBW for their CHP plants in Heilbronn and Altbach/Deizisau, near Stuttgart. What do these orders include?*

Raisin: This order is for the provision of gas turbines, steam turbines, generators and heat recovery steam generators – so the boilers. We will lead an international consortium for the projects. Our partners are Sener and Bonatti, which are an engineering and a construction company. The three of us are going to construct this power plant together for our customer EnBW.

EHP: *How big is the electrical and thermal output of the individual CHP plants? When should they go into operation?*

Raisin: The power plants will each have an output of 680 MW. We are working on the projects with our partner already, and have been for more than a year. The announcement kicks off the construction and manufacturing activities for the main equipment. That will lead to generating heat and power in 2027.

EHP: *The new gas fired CHP plants replace coal fired plants. What level of emissions does this save?*

Raisin: It's not a very new coal plant, first of all. So, the Coleman cycle high-efficiency equipment and sites will save 60% of the existing emissions. And that's the whole saving, by the way, of any coal-to-gas shift. For all of them – whether it's on CHP application or just on power generation – they will save at least 50% with the latest technology. And that's a big part of the transition that we need to consider.

EHP: *GE Vernova will deliver hydron-ready H-class gas turbines for the plants. What are the advantages of these turbines? How flexible are the systems?*

Raisin: There are two parts to your question. There are the advantages, and then the hydrogen advantages. The first advantage is a high efficiency that brings us this 50 to 60% CO_2 saving we spoke about. The gas turbines are cutting edge technology. And they also bring fast start on the power side but for the heat specificity, that's really this stable high-efficient heat generation. That is the main advantage of this technology.

EHP: *And what about the other advantage?*

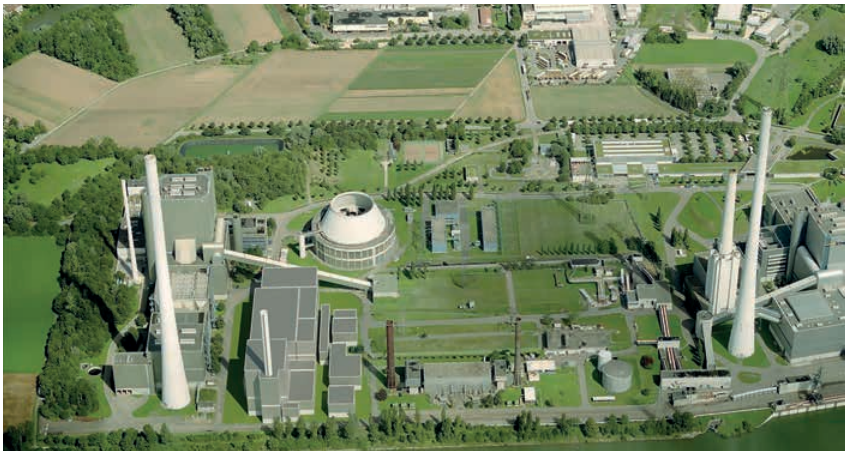
Raisin: The other one is the fact that from there we can further decarbonise with this technology on the combustion side, by burning other types of fuel – specifically hydrogen. So when these units are installed, we can burn a mix of gas and hydrogen, with hydrogen being 20% of the overall volume of fuel. And we plan to further develop the combustion system capabilities up to 100% hydrogen by 2030. For this plant, they will start with 20%, and whenever they have the right volume of hydrogen ready at site, we will be able to convert the combustion system to allow them to burn it.

Brice Raisin, Senior Executive Sales Leader Gas Power of GE Vernova

Source: GE Vernova

EHP: *How important are CHP plants for the energy transition?*

Raisin: I think in CHP there are two things that are really critical for



Visualisation of Altbach/Deizisau site after fuel switch

Source: EnBW Energie Baden-Württemberg/Rakete München

overall decarbonisation. One thing is that there is actually a way to decarbonise it. Because it's always the heat and the power. This is a great example: Moving coal to gas, you reduce 50% of your emissions at least, and that's a big step forward for any heat generation. There are huge targets to increase renewables in heat generation as part of the transition.

EHP: *And the other thing?*

Raisin: You need power to make an overall business case work for customers as well as making investment possible. For the system to work, you need CHP plants to be part of it. It's the case in Germany. It's the case in Poland. We have other projects, for example, in Poland that are very alike, where it's only with the subsidies coming from the power and the subsidy coming from heat together, that the system can start to be more efficient and generate less CO_2. CHP plays a unique role in participating in the power and heat generation decarbonisation.

EHP: *Isn't it also advantageous that you can start the plant very quick, because of the fluctuations in renewable energies?*

Raisin: Yes, this is extremely important. The gas plants today are the most dispatchable, efficient way to participate in the energy transition with a high share of renewables and then adjustment of the power generation on the grid from such plants.

EHP: *What do these orders from EnBW mean for your company? Is it the first order of this kind in Germany?*

Raisin: It is the first order for us in Germany in terms of H-class technology. We see it actually as one of the first orders on the market for such high-efficient power plants. It's not the first one for our company. GE Vernova has sold more than a hundred of these power plants, on H-Class, if you take 50 Hz and 60 Hz market. And we have more than a million operating hours on H-Class technology. We have a strong experience on H-Class, but this order is critical because it marks the start of the German phase of H-class power plant. The rest of the key players in the market: RWE, Uniper, Leag. They are all looking at this order as, hey, what are you doing and how and why and what are the technical capabilities? So, this is really critical for us.

EHP: *How important and big is the German market for you?*

Raisin: Our main work is services for existing fleet and new plants. Germany has ambitions of getting out of coal by 2030, with large renewable investment, and the backup power market, that represents gas, is 20 to 25 GW in the next years. This is as much as all of the sub-Saharan African continent. The only other country that will buy more gas plants in the same time frame is probably Saudi Arabia. This is how much of a priority Germany is for us and this is how important this first order from EnBW is for us.

EHP: *How important are hydrogen-ready CHP plants for Europe? How do you assess the market? Are there certain countries with high demand?*

Raisin: Germany is leading the way on that today, clearly. All the other European countries looking at investing in gas plants are asking about hydrogen capabilities at the same time. In 2022 we signed for a similar plant, 850 MW in Belgium, with a similar high-efficiency gas turbine. And this goes with the specific hydrogen content and roadmap to get to 2030 with 100% if necessary. So same story. Italy is the same. UK is asking us similarly. Poland is asking similarly for capabilities at installation. So Europe knows that we need gas plants as a deliverable and an economical way to generate electricity and to stabilise the grid. In addition, there is a way to make it more sustainable by either pre-combustion or with carbon capture post combustion side. The talks in general across Europe are more on the hydrogen and carbon capture side.

EHP: *Thank you for the interview.*

Silke Laufkötter

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Analyses of the Effectiveness of Cyclones for Cleaning Flue Gases after Burning Biofuels

This study investigates the performance of cyclones for a direct biofuel combustion plant with Computational Fluid Dynamics methods. The combustion occurs in the combustion chambers, and the required outlet temperature is provided by an excess of air. In order to compare the obtained data with real experience, the parameters of recirculation gases in fossil fuel boilers were selected. The research has been expanded to include the parameters required for combustion chambers. It was found that cyclones with optimal designs will operate at 92.51% efficiency.

Cyclones are commonly used in various industries to separate particles from gas streams. Cyclone separators play a crucial role in biomass gasification systems, serving as an effective tool for separating solid particles from the gas stream [1]. They find application in power plants [2], chemical plants, and various industries where dust or particulate matter needs to be removed. With increasing interest in renewable energy and environmental sustainability, biomass gasification has emerged as a promising technology to convert biomass into valuable fuels. The paper examines the operation of cyclones in combustion chambers when biofuel is burned directly [3;4]. It's a very similar process, but the operating temperature of such a cyclone is much higher. In this case, cyclones work similarly to cyclones in a boiler with circulating fluidised bed (CFB) [5;6]. In this paper, the computational fluid dynamics (CFD) research in studying cyclones after a combustion chamber will be discussed.

The biofuel combustion process produces solid particles (ash) and these particles need to be removed to ensure efficient fuel production and system operation. In this case, cyclone separators are necessary.

Cyclone separators, also known as cyclone dust collectors, are centrifugal separation devices designed to capture and remove solid particles from a gas stream. They work by imparting a rotational motion to the gas mixture, causing the heavier particles to be separated from the gas stream. The efficiency of cyclone separators can be attributed to several factors:

- Design: The design of cyclone separators plays a crucial role in their ability to capture and remove solid particles. The shape of the cyclone chamber and the internal baffle arrangement contribute to the efficient separation of particles from the gas stream.
- Flow rate and velocity: The flow rate of the gas through the cyclone separator also affects its performance. Higher flow rates can overwhelm the separator, resulting in reduced efficiency and increased particle emissions.
- Particle size and its density: The particle size of the biomass particles to be separated also affects the performance of cyclone separators. Coarse particles are more likely to settle and be removed, while smaller particles may require additional filtration or separation techniques.
- Operational conditions: The operating conditions, such as temperature, pressure, and moisture content, can affect the performance of cyclone separators. Higher temperatures and pressures can accelerate the setting of particles, improving separation efficiency. However, excessive moisture can hinder the separation process, requiring additional drying or dehumidification equipment.

CFD (Computational Fluid Dynamics) is a widely used tool in the scientific community for analysing and simulating various physical phenomena. When it comes to studying fluid flow and particle behavior in cyclone separators, CFD research offers unparalleled advantages [7].

CFD simulations can accurately predict and visualise the flow patterns and particle dispersion within a cyclone separator. By employing sophisticated computational algorithms and numerical techniques, CFD simulations can provide a detailed understanding of the gas distribution and particle behavior within these devices.

One of the key advantages of CFD research is the ability to examine the fluid flow characteristics within the cyclone separator. By simulating the fluid flow, analysing the behavior of the particles and tracking the motion of individual particles becomes possible. In addition to the flow and particle behavior, CFD simulations can also capture other

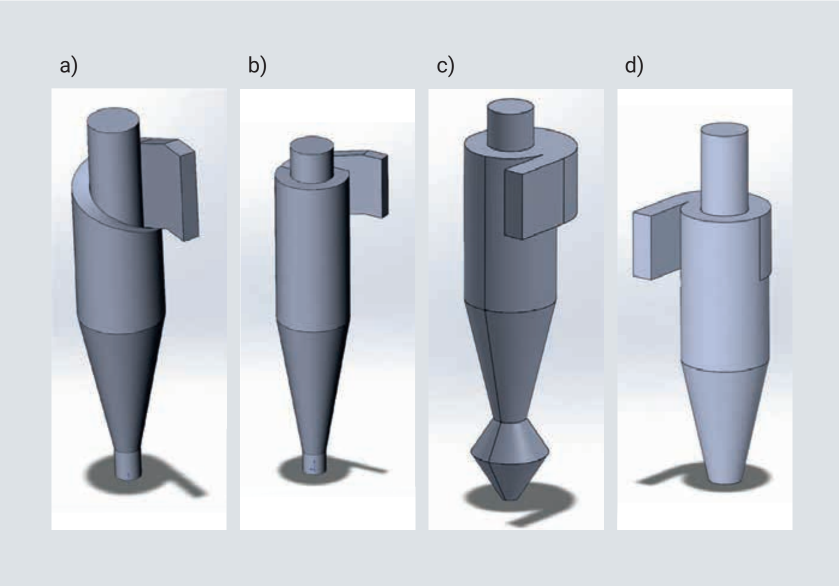

Figure 1. Four design versions of cyclone

important aspects of the cyclone separator, such as pressure drop or its efficiency. This analysis helps to identify areas that require optimisation or design modifications to enhance the performance of the separator.

This study aimed to develop the CFD model and determine the efficiency and aerodynamic resistance of cyclones for various designs. This work solved the following tasks:

- Selection of methods and models that provide the necessary accuracy (turbulence model, computational mesh size, etc.).
- An analysis of the efficiency and aerodynamic resistance of various designs of cyclones.
- Evaluation of the degree to which the fractional composition of ash and gas flow affects the cyclone's efficiency.

Description of simulation objects

Various designs of single cyclones were selected for modeling. There is a flow rate of 4.34 kg/s of gases through the cyclone at a temperature of 354 °C. A consumption of ash particles is 0.0434 kg/s (mass concentration – 0.0108 kg/kg). The parameters were chosen so that real experimental data could be compared. An analysis was conducted of the case of recirculation of combustion products in a fossil fuel boiler. Combustion products with thermophysical parameters corresponding to a gas temperature of 354 °C were studied (density $\rho = 0.577\ kg/m^3$, dynamic viscosity $\mu = 29.6 \cdot 10^{-6}\ Pa \cdot s$).

Four different design versions for cyclones are examined, with the main differences (from the perspective of efficiency) being the diameters of the body and inner pipe, as well as the orientation of the supply tangential channel. A cyclone design (Figure 1a) with an outer diameter of 1.4 m and an inclination angle of 24° was used in its first version. This was the study's initial version. The second version (Figure 1b) reduces the inclination angle of the supply channel to 15° and increases the cyclone body and inner pipe diameters to 1.7 m and 1.0 m, respectively. This is the optimised version.

The next two versions are commercial cyclones with selected parameters. Third version (Figure 1c) with horizontal gas supply duct and 1.7 m diameter housing is typical Condor Eco design. Contrary to the second version, this one uses an internal pipe with a smaller diameter (0.86 m). Figure 1d) shows the fourth version (cyclone SCN 50 800x4SP) which replaces a single cyclone by a battery of four cyclones of smaller diameter (0.8 m) with horizontal supply channels. In this simulation, four cyclones were included in one group.

Modeling method

RANS (Reynolds Averaged Navier-Stokes equations) with eddy viscosity models is the most effective way to solve engineering problems. A time-averaged Navier-Stokes equation is solved. The equations describe the behavior of the time-averaged flow and the pulsations in this method. The Shear Stress Transport (SST) model is based on the k-ω model. In most cases, Ansys recommends this model as the default. As a general principle, it uses k-ω near the wall and k-ε turbulence models at a distance from it. A fine mesh is required in order to take advantage of this model's potential. Based on regulatory materials, substances' properties were taken into account when calculating.

A mesh convergence study was conducted using several meshes. Meshes were created in Ansys Meshing software using several approaches. All meshes were generated using the „Automatic" method. This method is a combination of Delaunay, Sweep, and Advancing Front approaches.

Aspect ratio, skewness, and orthogonal quality were used to control mesh quality. In every case, mesh convergence was achieved. A difference of less than 1% was found between results from small meshes and big meshes. Each case consisted of at least eight cells across the gap, with the maximum size of the cell being only 0.01 m. The growth rate was set to 1.2 by default. For all three-dimensional models, the meshes that were used to model the final variants contained more than 20 million elements.

Design version	Particle consumption at the inlet [g/s]	Consumption of entrained particles [g/s]	Cyclone efficiency [%]	Aerodynamic resistance of a cyclone [Pa]
1	43.4	15.5	64.18	342
2	43.4	3.3	92.51	499
3	43.4	5.5	87.41	497
4	43.4	3.5	92.03	833

Table 1. Cyclones' efficiency and aerodynamic resistance

Modeling results

Calculations show the second version of the cyclone has the best particle collection efficiency with a 92.51% efficiency and an aerodynamic resistance of 499 Pa (Table 1). The combustion chamber should therefore be equipped with a cyclone of this design. Streamlines for this variant is shown in Figure 2.

Battery cyclone (version 4) also provides similar efficiency values (92.03%). This case, however, has a much greater aerodynamic drag (833 Pa). It is due to a slightly stronger twist in the cyclones and a dissipation of the dynamic pressure of the jets emanating from the cyclones in the upper collection box. With an aerodynamic drag close to the optimised version (497 Pa), version 3's efficiency is slightly less than the versions discussed above (87.41%). In the initial proposed design (version 1), the cyclone has the lowest calculated efficiency (64.18%). A cyclone of this design has a resistance of 342 Pa.

A cyclone's efficiency increases from 72.05 to 99.07% when the particle mean diameter increases from 5 to 70 µm. Figure 3 shows the dependence of cyclone efficiency on the mean particle size. Table 2 provides the corresponding numerical data. It has been demonstrated [8] that in the case of burning biofuels, the maximum particle size may not exceed 10 µm. Figure 3 shows this case with a red line. It is shown that even in this case, the cyclones have an efficiency of 80%, which is quite high. For the conditions previously studied [3;4], the required degree of purification of gases from ash particles is about 70%. Therefore, the necessary gas purification will still be achieved even if the dust particle size is very small (less than 10 µm).

There is a direct correlation between temperature density and viscosity in the medium, so as the temperature increases, the efficiency of the cyclones also changes. Flow rate of the medium in the present study was changed in such a way that the velocity inside the cyclone remained unchanged. Figure 4 shows the results of the study. A cyclone's efficiency drops from 92.51% to 78.72% as temperature increases from 350 °C to 1,600 °C. The cyclone is 79.13% efficient at the

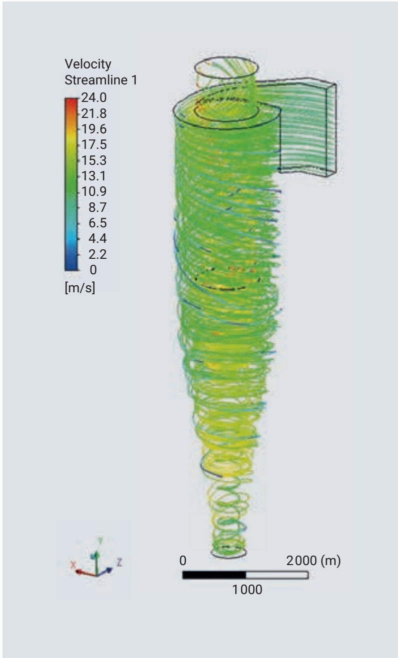

Figure 2. Streamlines for cyclone's design variant 2

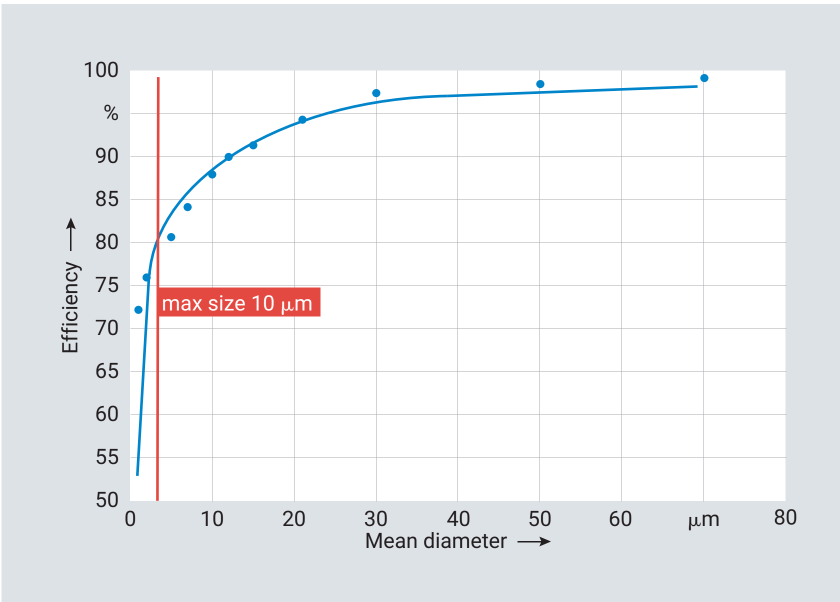

Figure 3. The effect of mean particle size on cyclone efficiency

Particle dimensions, µm			Particle consumption at the inlet [g/s]	Consumption of entrained particles [g/s]	Cyclone efficiency [%]
Min	Mean	Max			
0.04	1	3	43.40	10.49	72.05
0.08	2	6	43.35	8.44	75.84
0.2	5	14	43.30	6.91	80.54
0.3	7	20	43.35	5.27	84.03
0.4	10	27	43.14	4.37	87.83
0.5	12	34	43.33	3.80	89.88
0.6	15	43	43.38	2.51	91.22
0.5	21	80	43.53	1.17	94.21
1.3	30	86	43.36	0.71	97.32
2.1	50	143	43.36	0.40	98.36
2.9	70	201	43.38	<0.01	99.07

Table 2. Results of the particle size study

temperature chosen for research (1,200 °C) [3;4]. This is much higher than the required 70%.

Since cyclone efficiency can vary depending on gas flow rate, particle collection efficiency should be checked at both rated and reduced loads. In this simulation, half the nominal gas flow rate was used for the cyclone operation. The calculation shows that when the gas flow rate through the cyclone is reduced by two times, the flow structure does not change significantly. The velocity level is reduced by approximately two times. Approximately four times the decrease in resistance from 499 to 120 Pa represents a quadratic relationship. In comparison with the variant with a rated load, when the gas flow rate was reduced by two times, the calculated efficiency of the cyclone remained practically unchanged.

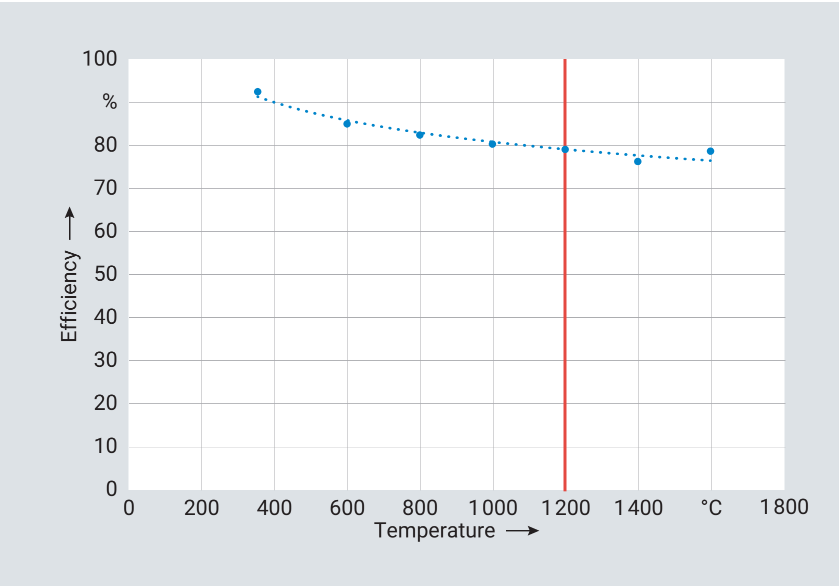

Figure 4. Temperature dependence of cyclone efficiency

Conclusion

Optimising the cyclone design increased efficiency from 64.8% to 92.51%, which is not worse than commercial cyclones (version 3) or battery cyclones (version 4). It was also possible to maintain a competitive aerodynamic resistance (499 Pa). Battery cyclones have higher aerodynamic resistance (833 Pa).

It is expected that a decrease in particle size and an increase in flow temperature would reduce cyclone efficiency. The cyclone efficiency was about 80% in both cases after reducing the particle size and increasing the flow temperature to the levels required in this study. It will be necessary to conduct a study after developing specific solutions for burning a certain biofuel to determine the degree of purification of gases from particulate matter.

The efficiency of the cyclone was virtually unaffected by reducing the cyclone load. It occurs because the magnitudes of force acting on particles from the gases, as well as the centrifugal force, are proportional, respectively, to the square of the particle's velocity relative to the gases and to the square of the flow's rotational speed.

Acknowledgement

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References

[1] Surjosatyo, A.; Respati, A.; Dafiqurrohman, H.; Muammar: Analysis of the Influence of Vortexbinder Dimension on Cyclone Separator Performance in Biomass Gasification System. Procedia Eng, Vol. 170, 2017.

[2] Song, G.; Yang, Z.; Lyu, Q.: Investigation of gas-solid flow and temperature distribution uniformity of 350 MW supercritical CFB boiler with polygonal furnace. Powder Technology 355, 2019.

[3] Zaichenko, M.; Khokhlov, D.; Sterkhov, K.: The Promising Combined-cycle Power Plant with Biofuel Usage. EUROHEAT&POWER (English Edition), IV/2022,p. 22-27.

[4] Zaichenko, M.; Khokhlov, D.; Sterkhov, K.; Maslov R.: An Evaluation of Direct Combustion of Biofuels in the Combustion Chamber of a Promising CCGT. EUROHEAT&POWER (English Edition), IV/2023, p. 32-37.

[5] Gu, J.; Liu, Q.; Zhong, W.; Yu, A.: Study on scale-up characteristics of oxy-fuel combustion in circulating fluidized bed boiler by 3D CFD simulation. Advanced Powder Technology Vol. 31, 2020.

[6] Deng, B.; Zhang, M.; Shan, L.; Wei, G.; Lyu, J.; Yang, H. et al.: Modeling study on the dynamic characteristics in the full-loop of a 350 MW supercritical CFB boiler under load regulation. Journal of the Energy Institute Vol. 97, 2021.

[7] Brar, L.S.; Sharma, R.P.: Effect of varying diameter on the performance of industrial scale gas cyclone dust separators. Materials Today Proceedings, Vol. 2, 2015.

[8] Åmand, L.-E.; Leckner, B.; Eskilsson, D.; Tullin, C.: Deposits on heat transfer tubes during co-combustion of biofuels and sewage sludge. Fuel 85 (2006) 1313-1322

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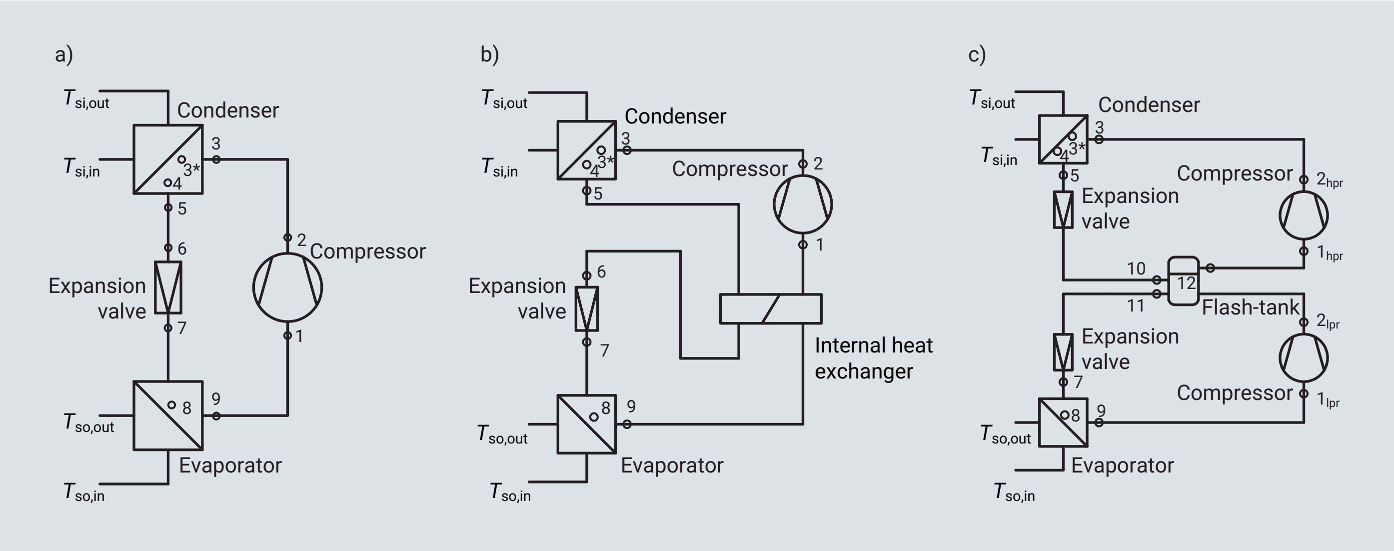

Figure 1. Investigated heat pump circuits; a) basic heat pump model, b) single-stage compression with an internal heat exchanger (IHX), c) two-stage compression and intercooling with two-stage expansion of the refrigerant

Feasibility Study Concerning Process Heat Supply in a District Heating System with Heat Pump

In recent years, the use of industrial waste heat as a heat source for high-temperature heat pumps has become increasingly important [1;2]. In order to analyse further applications in the district heating sector, this article deals with a parameter study.

In the district heating sector, the flow and return temperatures in existing networks are gradually lowered, e.g., to reduce heat losses. District heating systems cannot then supply consumers with higher temperatures (e.g., above 120 °C). The possibility of using the supply or return flow as a heat source also offers potential for high-temperature heat pumps. District heating operators can then take over the assignment of process heat supply or develop new customers.

Numerous influencing variables (such as different refrigerants, circuits, heat source temperatures) affect the heating capacity or efficiency of high-temperature heat pumps. Therefore, it is important to find an optimal heat pump solution for the respective boundary conditions.

To solve this problem, various refrigerants have been investigated, including natural refrigerants (R600, R601a, R744), HFO refrigerants (R1234ze(E), R1336mzz(Z)), and HCFO refrigerants (R1224yd(Z), R1233zd(E)). Furthermore, improvements in the process can be achieved by modified circuits (e.g., internal heat exchanger, two-stage compression and intercooling with two-stage expansion). The heat pump inlet temperature on the source side is 50 to 100 °C. The target temperature of the heat supply is 140 °C (e.g., steam supply). All systems were modeled and simulated using the Ebsilon Professional program [3]. In the investigations, the Coefficient of Performance (COP) was determined as an essential parameter. This in turn allows an optimal preselection of heat pumps. These systematic investigations show the functional progression of the COP, which promotes a better understanding of the problem. The results provide information for the district heating sector and industry to promote the use of high temperature heat pumps in district heating areas.

New district and local heating systems are designed with the lowest possible supply and return temperatures. Operators also strive to lower temperatures in existing networks. These efforts are primarily aimed at minimising heat losses. As a result, direct supply of process heat to customers (e.g., above 120 °C) is no longer feasible.

This problem can be solved by using high-temperature heat pumps (HTHP). In principle, the supply or return flow can be utilised as a heat source, allowing individual consumers in the network area to be supplied with heat at temperatures above 120 °C (superheated water or steam). This could form the basis for an interesting business model if low heat production cost can be achieved. In that case, district heating operators could attract new customers and increase sales.

The COP for Heating ε_H (energy efficiency of process) and heating capacity of HTHP are influenced by various factors. The choice of refrigerant (ODP = 0, GWP < 5), the circuits, and the heat source temperatures play an important role [4-6]. Therefore, it is crucial to find an optimal heat pump solution tailored to the specific boundary conditions. To gain a comprehensive understanding of the problem, systematic simulations and analyses were conducted using Ebsilon Professional [3].

In this article, the configurations of the researched circuits are introduced and the chosen refrigerants are presented. Furthermore, the authors explain the boundary conditions of the simulations. The simulation results are focus on the COP for Heating, Compression ratio and Heat production cost, which are presented and evaluated before the conclusion.

Models and investigations

Circuit

Figure 1 shows the three investigated heat pump circuits. These circuits were chosen due to their wide prevalence in practice. Figure 1a) shows the basic circuit of a heat pump (referred to as the basic heat pump model), which consists of four main components: the compressor, condenser, expansion valve, and evaporator. The second circuit (Figure 1b), referred to as single-stage compression with an internal heat exchanger (IHX) extends upon the basic heat pump model and includes an additional internal heat exchanger. The internal heat exchanger can improve the COP by further cooling the refrigerant before it enters the expansion device, thereby increasing the suction temperature of the refrigerant. In the third circuit (Figure 1c), referred to as two-stage compression and intercooling with two-stage expansion of the refrigerant), two compressors (low- and high-pressure stage) are used. Phase separation occurs in an intermediate cooler (flash tank) [2;7].

All the above-mentioned circuits were modeled and then simulated using the Ebsilon Professional software. A specific control code (EbsScript) is used to handle the parameter variations. The code varies specific parameters (such as the inlet temperature on the heat source side, $T_{so,in}$, and the suction superheat, T_{SH}), and then initiates the simulation. Subsequently, a Matlab script verifies the data again to filter out results that do not comply with the simulation boundary conditions. This allows for the determination of results under the given boundary conditions.

Refrigerants

Within this study, seven refrigerants, R600, R601a, R744, R1224yd(Z), R1233zd(E), R1234ze(E), and R1336mzz(Z), are investigated. Table 1 summarises the main properties of the refrigerants. Nowadays, natural refrigerants are gaining attention due to environmental and economic concerns. Therefore, natural refrigerants are compared to

Refrigerants	Substance group	Chemical formula	T_0 (1 bar) (°C)	T_{crit} (°C)	p_{crit} (bar)	ODP	GWP	SG
R600	alkane	$CH_3CH_2CH_2CH_3$	-0.5	-152.0	38.0	0	4	A3
R601a	alkane	$(CH_3)_2CHCH_2CH_3$	27.8	187.2	33.8	0	3	A3
R744	nature refrigerant	CO_2	-78.5	31.0	73.8	0	1	A1
R1224yd(Z)	HCFO	$CF_3CF = CHCl(Z)$	14.0	155.5	33.3	0	< 1	A1
R1233zd(E)	HCFO	$CF_3CH = CHCl(E)$	14.0	166.5	36.2	0	1	A1
R1234ze(Z)	HFO	$CF_3CH = CHF(Z)$	9.8	150.1	35.3	0	< 1	A2L
R1336mzz(Z)	HFO	$CF_3CH = CHCF_3(Z)$	33.4	171.3	29.0	0	2	A1

Table 1. Categorisation and properties of the investigated refrigerants [1]

synthetic refrigerants (hydrofluorolefins (HFO), and hydrochlorofluoroolefin (HCFO)) within the scope of this study. The selected refrigerants have different safety classifications ranging from A1 to A3, thus covering a broad range of current and future refrigerants. All the refrigerants have an Ozone Depletion Potential (ODP) of zero and a Global Warming Potential (GWP) of less than five, thus complying with applicable policy regulations.

Additionally, all the selected refrigerants (except R744) have critical temperatures above 150 °C, indicating that they can operate with subcritical state changes. Only the HTHP using R744 operates in the supercritical range. In this case, a very large temperature difference in the gas cooler is required to achieve high COP. Therefore, the HTHP using R744 is a special case.

Boundary conditions

In the simulation, except for the R744 heat pump operating in the supercritical range, the condensing pressure p_c and the evaporating pressure p_0 can be calculated using the condensing temperature T_c and the evaporating temperature T_0. The compressor discharge temperatures T_2 can be determined for the respective pressures. Similarly, the inlet temperature on the heat source side, $T_{so,in}$, was determined in the range of 50 to 100 °C. The temperature difference between the inlet and outlet on the heat source side is 5 K.

The superheating range of the suction gas is defined from 5 to 20 K [2]. In this study, the lowest possible superheat has been selected for refrigerants and circuits (except for R744). In circuit a) and circuit c), the superheating is 5 K for the refrigerants (R600, R1224yd(Z), R1233zd(E), R1234ze(Z)). This ensures that the compressor suction gas remains in a gaseous state. For refrigerants R601a and R1336mzz(Z), the authors set a superheating of 20 K to ensure that the compressor does not enter the two-phase region of the refrigerant during operation.

For the circuit b), the refrigerant first passes through the internal heat exchanger before entering the compressor. Compared to circuits a), this increases the superheating of the refrigerant before it enters the compressor. If the condensing pressure p_c remains constant, the compressor discharge temperature T_2 increases. To ensure that the compressor discharge temperature T_2 remains within a reasonable range ($T_2 < 150$ °C), a superheating of 0 K was chosen for refrigerants R600, R1224yd(Z), R1233zd(E), and R1234ze(Z), and a superheating of 15 K was chosen for refrigerants R601a and R1336mzz(Z).

The control of the R744 heat pump model is determined based on the compressor discharge pressure p_2. To ensure better comparability, the authors of this study choose a discharge pressure p_2 below 150 bar and a compressor discharge temperature T_2 in the same range ($T_2 < 150$ °C) for all simulations, as mentioned above.

Based on the study [8], the isentropic efficiency η_{is} is set to 0.7 for all simulations. The project Research Platform for Refrigeration and Energy Technology Ketec Subproject 10 [9] focuses on the storage and provision of process heat. Therefore, the inlet temperature on the heat sink side $T_{si,in}$ is set to 120 °C, and the outlet temperature of the heat sink side $T_{si,out}$ is set to 140 °C (condenser). To achieve comparable COP, the inlet temperature

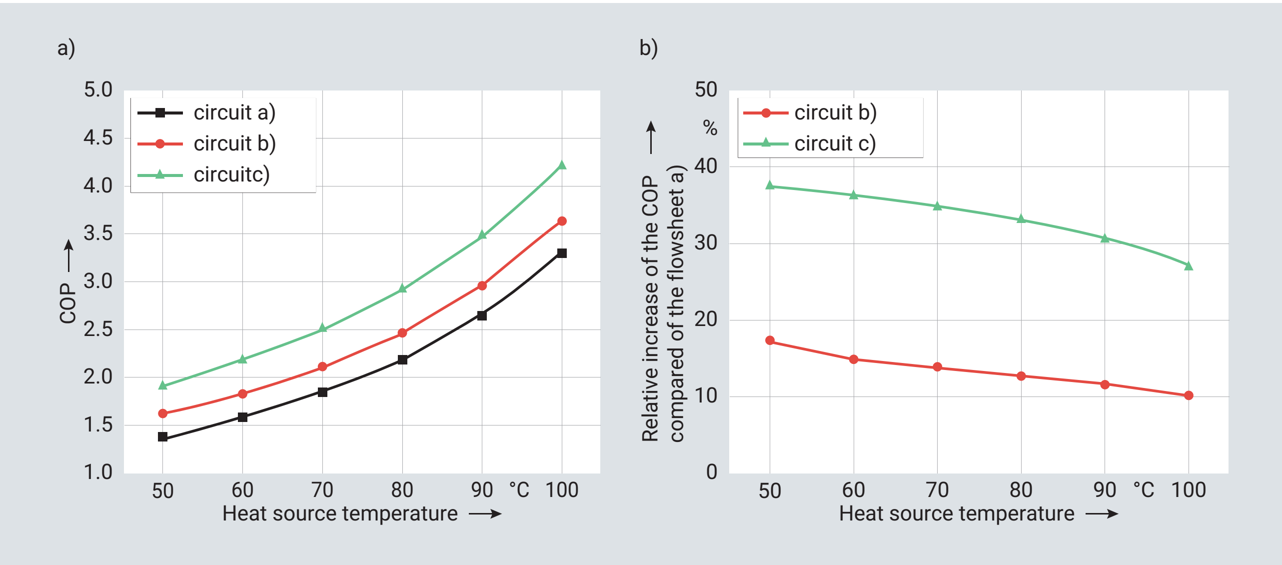

Figure 2. Simulation results for the refrigerant R1224yd(Z); a) dependence of the COP on the source temperature and the circuits according to Figure 1; b) relative increase of the COP compared to the circuit a)

of the heat sink side $T_{si,in}$ is set to 10 °C for the R744 heat pump (exception due to the substance properties).

In an early phase of the work, the generation of superheated water and superheated steam in the condenser was investigated. However, the simulation results showed that the influence of both variants on the COP is negligibly small. Therefore, the following discussion is based on the case of superheated water production.

Results and discussion

COP for Heating

The energetic efficiency of the HTHP is to be evaluated solely based on the COP for Heating ε_H. Figure 2a) shows an example of the COP achievable with refrigerant R1224yd(Z) using the three circuits at different heat source temperatures. According to the COP, circuit c) demonstrates a clear advantage over the other two variants. Circuit a) is the least advantageous. Figure 2b) illustrates the relative increase in COP for circuit b) and circuit c) compared to circuit a). On average, the relative increase is 13% (circuit b)) and 33% (circuit c)). It can be observed that the improvement in COP due to the change in circuits has a greater impact at lower heat source temperatures. However, as the heat source temperature increases, the improvement in COP gradually decreases.

R1224yd(Z) is a representative example to demonstrate the trend of the COP for the different circuits

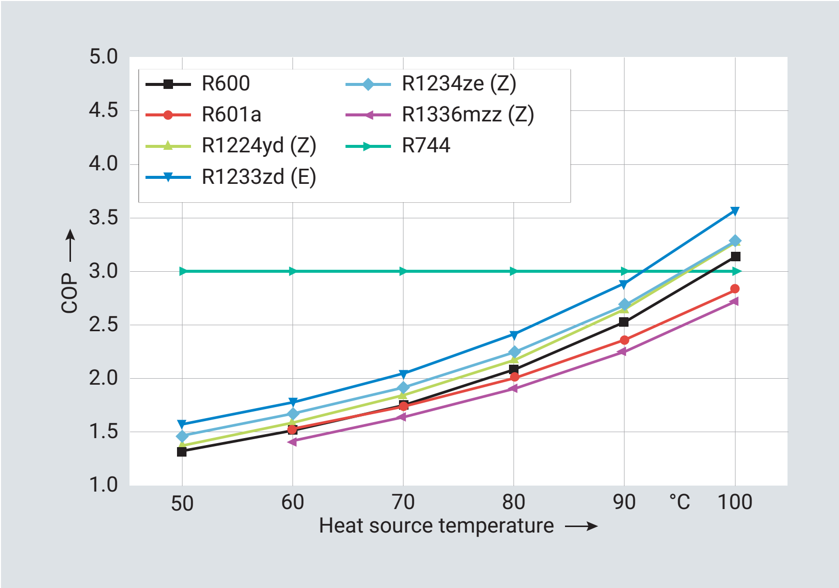

Figure 3. Dependence of the COP on the source temperature and the refrigerants for the circuit a)

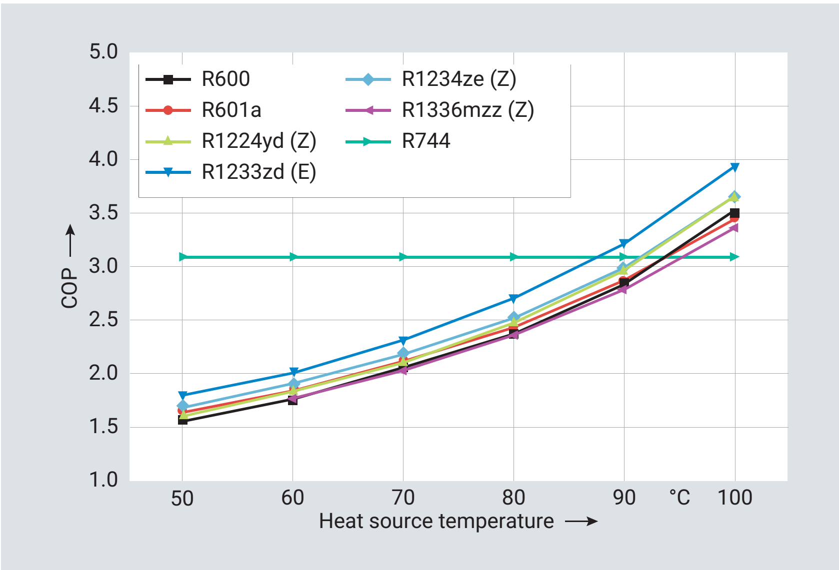

Figure 4. Dependence of the COP on the source temperature and the refrigerants for the circuit b)

and heat source temperatures. Among the remaining five refrigerants (except for R744) introduced at the beginning of the article, the simulation results show the same trend as with R1224yd(Z). The re-

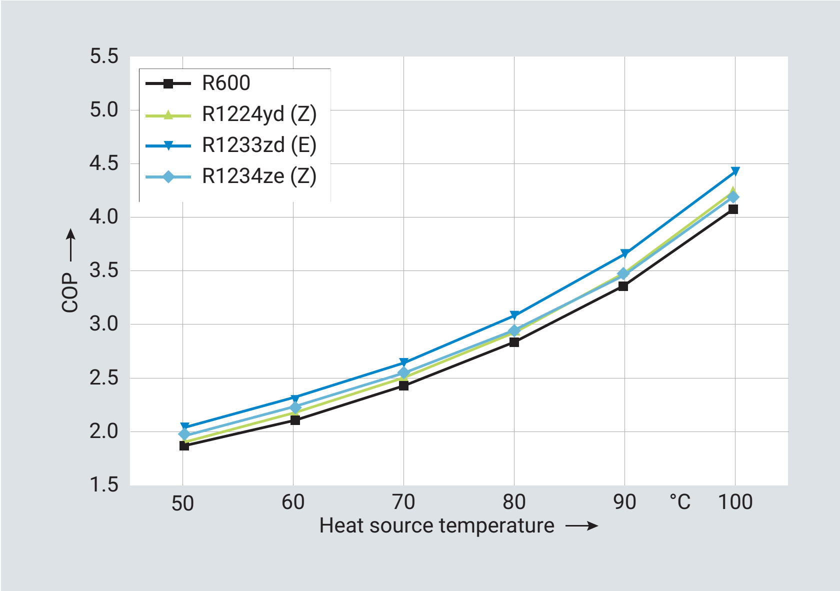

Figure 5. Dependence of the COP on the source temperature and the refrigerants for the circuit c)

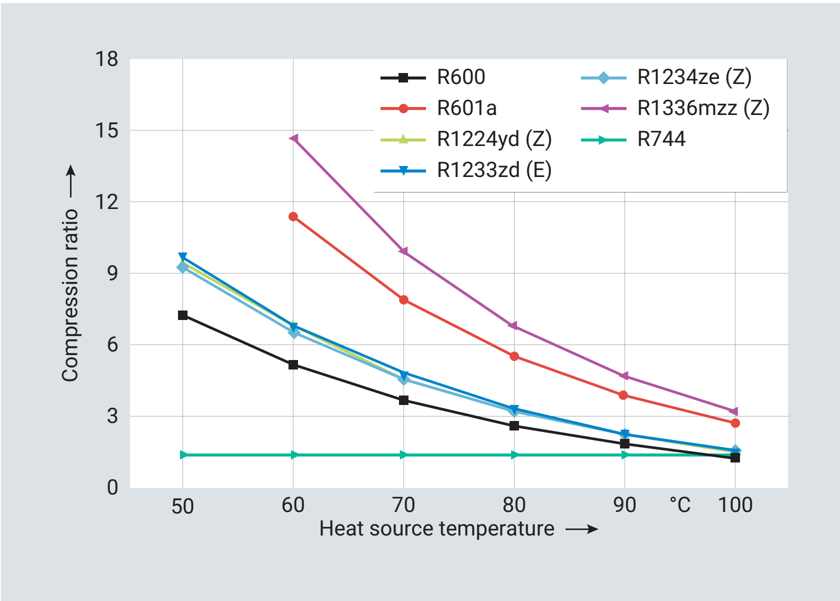

Figure 6. Dependence of the compression ratio on the source temperature and the refrigerants for the circuit a)

sults can be seen in Figure 3 to Figure 5.

It should be noted that due to the limited boundary conditions, the seven refrigerants in this study cannot cover all heat source temperatures for all the three circuits. These limitations are also visible in Figure 3 to Figure 5. For example, in circuit c) with refrigerants R601a and R1336mzz(Z), the compression process of the high-pressure stage enters the two-phase region. Therefore, these two refrigerants are not included in Figure 5. When the heat source temperature is 50 °C, the points (R601a, circuit a); R1336mzz(Z), circuit a) and circuit b)) are not present in Figure 3 and Figure 4. This is because the corresponding evaporating pressure is below 1 bar.

R744 stands out among the seven refrigerants, primarily due to its low critical temperature (Table 1). As a result, the process operation must be in the supercritical range. This allows for higher COP at low heat source temperatures compared to the other refrigerants. However, due to the limited boundary conditions, the COP for R744 reach a limit of approximately three as the heat source temperature increases. For circuit c), R744 is also unsuitable due to its lower critical temperature. Therefore, no simulation results for R744 are shown in Figure 5.

Based on Figure 3 and Figure 4, it can be observed that R744 achieves the highest COP with circuit a) and circuit b) at heat source temperatures between 50 and 90 °C. R1233zd(E) achieves the highest COP with circuit c). If R744 is not considered for circuit a) and circuit b), R1233zd(E) can achieve the highest COP.

Compression ratio

Compression is an important process in heat pumps, and reducing the compression effort is crucial. Without going into the actual implementation (such as the use of a compressor), the aim in below is to complement the results shown above and provide a better understanding of the operating ranges.

Figure 6 illustrates the functional relationship between compression ratios and heat source temperatures for various refrigerants. This figure is based on circuit a), where the condensing temperature remains constant. A lower compression ratio implies that the compressor can perform less work.

Figure 7 shows the pressure difference between the inlet and outlet of the compressor. Although R744 has the lowest compression ratio among all refrigerants, it still has the highest-pressure difference. For the other refrigerants, R1336mzz(Z) and R601a, the compression ratio is relatively high. However, the pressure difference remains below 30 bar.

Heat production cost

The cost of heat production is a good way to assess or estimate economic feasibility in the sense of marginal cost analysis. At the same time, the results of different heat pump circuits with different refrigerants can be better compared. This means that only operating cost are considered, while other cost (such as investment cost) are not taken into account. In the past years (2017-2021), it has been observed that the use of zero-emissions electricity may have higher purchase cost compared to conventionally generated electricity [10]. However, due to increasing prices for conventional energy supply and decreasing prices for e.g., PV systems, the situation may be reversed in the present and upcoming years.

Figure 8 presents the results of an investigation of heat production cost. The two sub-figures differ in terms of the selected COP (Figure 8a): ε_H: 2.05; Figure 8b): ε_H: 4.44).

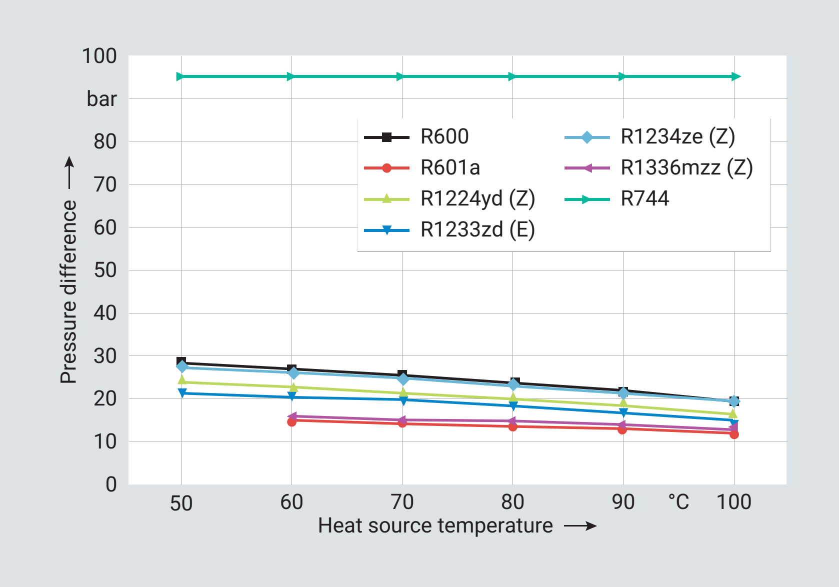

Figure 7. Dependence of the pressure difference on the source temperature and the refrigerants for the circuit a)

They indicate the lowest and highest COP for circuit c) (refrigerant: R1233zd(E)).

To calculate the cost of heat production, the electricity purchase cost was varied from €0.00 /kWh to €1.00 /kWh and the heat purchase cost (district heating return flow) was varied from €0.00 /kWh to €1.00 /kWh as well. The red dashed lines in the figures represent the cost of heat production, with a price difference of €0.10 /kWh between each two lines. In this calculation method, the COP of the heat pump is the only factor considered. Therefore, the slope of the red dashed lines (iso-lines of heat production cost) becomes steeper as the COP increases. This behavior can be clearly seen in Figure 8. With the help of Figure 8, the district heating supplier or customer can quickly estimate the marginal cost.

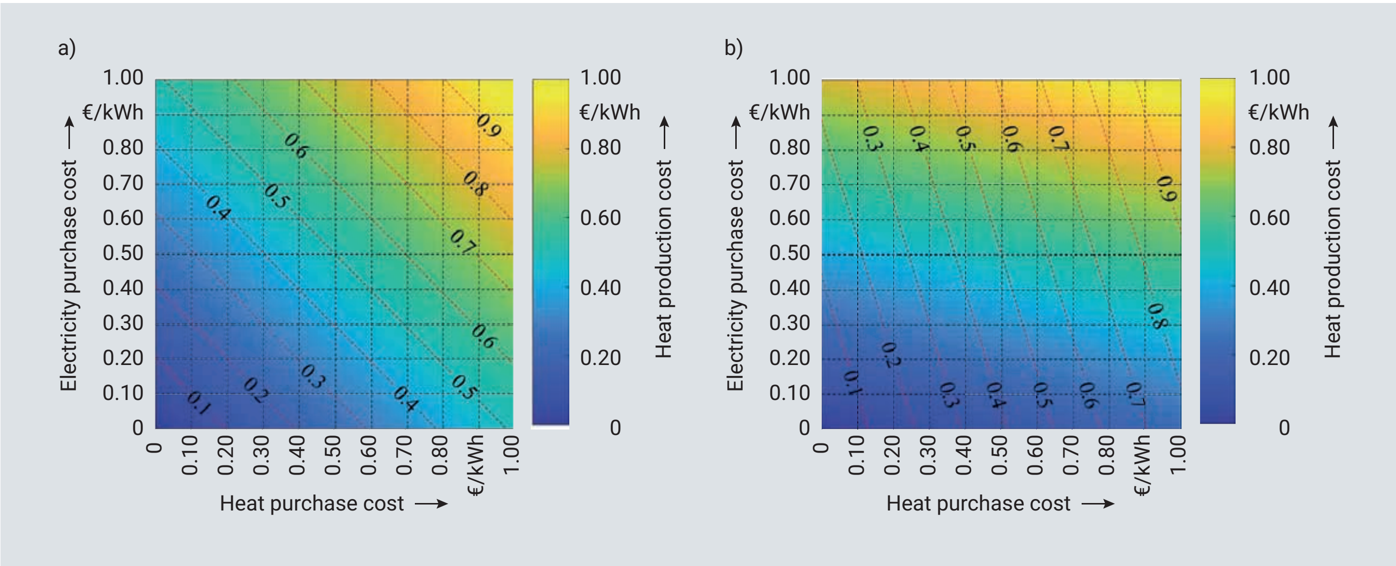

Figure 8. Dependence of the heat production cost on the electricity purchase cost and heat purchase cost (a) ε_H: 2.05, R1233zd(E); b) ε_H: 4.44, R1233zd(E))

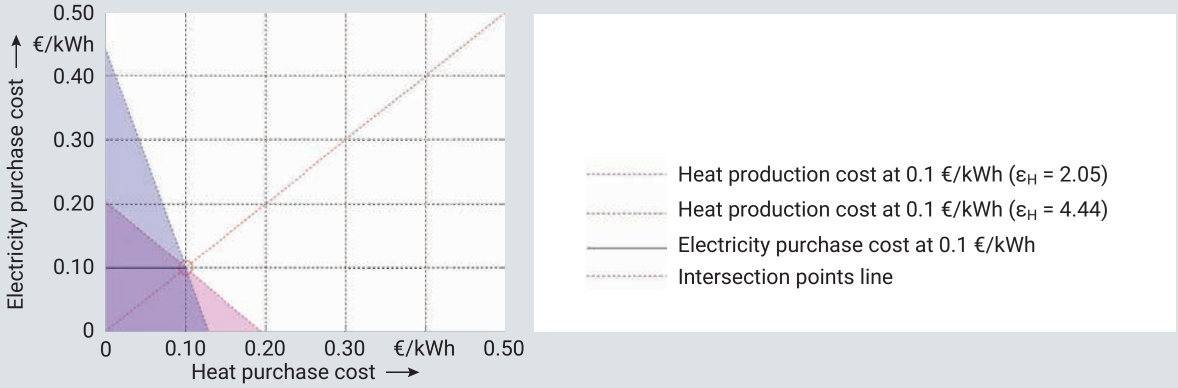

Figure 9. Comparison of the heat production cost using different COP

Figure 9 is derived from Figure 8. The pink and blue dashed lines represent the cost of heat production at €0.10 /kWh for the two COP (ε_H: 2.05 and ε_H: 4.44). The shaded areas below these lines indicate the cost of heat production below €0.10 /kWh. The shaded area increases as the COP increases (only the case with COP > 2 was considered). For the operator, a larger shaded area means greater flexibility in response to changes in electricity and heat purchase cost. The heat production cost lines intersect under the same cost (but different COP). Connecting all the intersection points results in the red dashed line in Figure 9.

Conclusion

In total, three heat pump circuits and seven refrigerants were analysed for heat supply at 140 °C (superheated water or steam) in this study. A fictitious district heating system (supply or return flow) served as the heat source. Circuit c) yielded the highest COP. However, specific considerations need to be made regarding the refrigerants. Using circuits a) and b), R744 achieved the highest COP at lower heat source temperatures (T_{so}: 50...80 °C). The other refrigerants showcased their advantages at higher heat source temperatures (T_{so}: 100 °C). In circuit c), R1233zd(E) achieved the highest COP, reaching a maximum value of 4.44. As a competing technology, direct electric heating (expected cost of heat production at €0.10 /kWh) can be considered. To remain competitive, a higher COP allows for a wider acceptable range of electricity and heat purchase cost. In the present example, to achieve a heat production cost below €0.10 /kWh with an ε_H of 4.44 (R1233zd(E)), the electricity purchase cost would have to be below approximately €0.45 /kWh and the heat purchase cost would have to below approximately €0.12 /kWh. Therefore, high COP are critical to achieving the expected low cost of heat production.

All the circuits were modeled, simulated, and systematically analysed using Ebsilon Professional software to select suitable heat pump solutions. The results provide fundamental insights and functional relationships for the district heating and industrial sectors. The aim is to expand the application potential of high-temperature heat pumps and replace conventional solutions with greenhouse gas emissions and high costs. The marginal cost analysis revealed a cost range of heat production below €0.10 /kWh. Further efforts are required to offer process heat affordably, securely, and in an environmentally friendly manner. In subproject 10 of the Ketec research project, this is a central focus area. Thermal energy storage systems are envisaged to compensate for fluctuating energy supply and variable heat demand over time. The authors see considerable development and application potential here.

Acknowledgement

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References

[1] Arpagaus, C.: Hochtemperatur-Wärmepumpen Marktübersicht; Stand der Technik und Anwendungspotenziale. VDE Verlag GmbH, Berlin, Offenbach, 2019.

[2] Höges, C.; Roskosch, D.; Brach, J.; Vering, C.; Venzik, V.; Müller, D.: In-

List of Symbols	
Latin letters	
p	pressure (bar)
T	temperature (°C)
Greek letters	
ε_H	Coefficient of Performance for Heating (-)
η	efficiency (-)
Indexes and abbreviations	
0	evaporation
c	condensation
COP	Coefficient of Performance for Heating
crit	critical
GWP	Global Warming Potential
HCFO	hydrochlorofluoroolefin
HFO	hydrofluoroolefins
hpr	high pressure
HTHP	high-temperature heat pump
in	inlet
is	isentropic
lpr	low pressure
ODP	Ozone Depletion Potential
out	outlet
SG	safety group based on SN EN 378-1: 2017 und ASHRAE Standard 34
SH	superheating
si	heat sink
so	heat source

vestigation of the Interactions between Refrigerant. Energy Technol. Vol. 11 (2023).

[3] Iqony Solutions GmbH. Ebsilon Professional 16 P1, 2023.

[4] Ozone Secretariat, United Nations Environment Programme. The Montreal Protocol on Substances that Deplete the Ozone Layer. Montreal, 1987. URL: https://ozone.unep.org/treaties/montreal-protocol [access: 05.05.2023].

[5] European Parliament. Regulation (EU) No 517/2014 of the European Parliament and of the Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006, 2014.

[6] United Nations Treaty Collection. Chapter XXVII Environment.2.f. The Montreal Protocol on Substances that Deplete the Ozone Layer, Kigali, 2016. URL: https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no =XX-VII-2-f&chapter=27&clang=_en [access: 05.05.2023].

[7] Bruno, F.; Belusko, M.; Halawa, E.: CO_2 Refrigeration and Heat Pump Systems – A Comprehensive Review. Energies (2019).

[8] Wang, J.; Belusko, M.; Liu, M.; Evans, M.; Alemu, A.; Bruno, F.: Preliminary Study On A Novel Transcritical CO_2 High-Temperature Heat Pump. Proceedings of the 6th International Seminar on ORC Power Systems, Technical University of Munich, 2021.

[9] Urbaneck, T.; Matthes, M.; Richter, M.; Hempel, O.; Safarik, M.; Franzke, U.; Noack, R.; Honke, M.; Müller, M.; Henninger, S.; Schossig, P.; Henning, H.-M.; de Oliveira, H. T.; Morgenstern, A.; Nienborg, B.; Gschwander, S.; Engelmann, P.; Benndorf, G. www.ketec.online. Website of the joint project, 30.05.2023.

[10] Nefodov, D.; Xiao, S.; Richter, M.; Urbaneck, T.: Nutzung eines Fernwärme-Rücklaufs als Wärmequelle zur Versorgung eines Nahwärmenetzes mit Wärmepumpen – Teil 2. HLH Lüftung/Klima Heizung/Sanitär Gebäudetechnik VDI Fachmedien 72. (2021) Vol. 6, pp. 59-63.

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Short Comparison of District Heating Development Potential in Germany and France

District heating and cooling systems play a crucial role in the transition to more sustainable energy sources. It is therefore important to determine how great the district heating development potential is. At HafenCity University a study was carried out to draw an exemplary comparison between France and Germany.

Energy represents a major challenge in modern society, and in Europe, nearly half of the final energy demand is attributed to heating and cooling. This highlights the crucial importance of finding sustainable solutions to meet these energy needs, especially in large cities that face significant seasonal challenges. Indeed, winter and summer can pose considerable challenges in terms of the supply of renewable energy for heating and urban cooling. However, amidst these energy challenges, promising technologies are emerging that pave the way for more efficient integration of renewable energy sources. Among these technologies, district heating and cooling systems stand out as potentially crucial solutions.

At HafenCity University, Hamburg/Germany, a study was carried out during an Erasmus Internship, to draw an exemplary comparison between France and Germany on the district heating development potential. Emblematic case studies, such as Paris-Berlin and Bordeaux-Hamburg, were used to analyse the development of the networks and suggest renewable energy sources suitable for future networks. Here is an overview of the characteristics of each city in 2022:

- Paris, the French capital, had a population of 2,117,702, according to the French National Institute for Statistics and Economic Studies (INSEE). Management of Paris's district heating and cooling networks was divided between two separate entities: CPCU, responsible for the district heating network, and Fraicheur de Paris, responsible for the district cooling network. The heating network is 521 km long.
- Berlin, the German capital, had a population of 3,755,251 in 2022, according to data from Statista. Berlin's heating network is characterised by its diversity, with large networks and smaller ones. The main heating networks are managed by major players such as Vattenfall Wärme Berlin AG (with a length of 2,000 km), Fernheizwerk Neukölln AG (with a length of 118 km) and BTB GmbH (with a length of 140 km). District cooling in Berlin was split between two sites: Potsdamer Platz, managed by Vattenfall, and Adlershof, managed by BTB.
- Bordeaux Seaport-Métropole, located in south-west France, has a population of 264,506 according to INSEE. Its district heating network comprises some sixteen separate networks with a total length of no more than 100 km, plus four cooling networks.
- The city of Hamburg Seaport-Metropolis in Germany has a population of 1,892,122. The city's main district heating network is managed by Hamburger Energiewerke with a network length of 845 km, while other networks, such as Urbana Energiedienste GmH and Vattenfall Energy Solution GmbH, also play an important role. This study focused on the Hamburger Energiewerke network in Hamburg, with a special mention for the unique district cooling network located in City Nord.

This background will enable to examine in more detail the opportunities and challenges associated with setting up district heating networks in these dynamic and diverse cities.

Methodology

The main objective was to create a map covering the whole region and highlighting the areas with the greatest potential for developing heating networks. The accuracy sought had to be sufficient to identify neighbourhoods with high potential, in order to facilitate the geographical targeting of future in-depth feasibility studies. The simplified methodology will be based on that given in the 2020 guide to identifying heating and cooling network projects drawn up by Amorce[1]. The data was found in

[1] Amorce, Guide d'identification de projets de réseaux de chaleur et de froid, 2020.

open data and was manipulated using Arcgis Pro software.

First of all, several data points on the different cities had to be resembled, such as :

- Mapping the existing heating and cooling network, with the production sites located there;
- Drawing up a preliminary route for the heating network using existing road sections;
- Determine the annual consumption of the various buildings in the town under study. However, if these data have not been found in the open data databases of the cities studied, an approximation with the equations 1 and 2 have been made.

$$E_{H,1} = A_B \cdot E_{H,avg} \qquad \text{Eq. 1}$$

Where:
$E_{H,1}$ = =energy consumption of buildings in terms of heat [kWh],
A_B = floor area of the building [m^2],
$E_{H,avg}$ = average consumption of heat or cooling per m^2 in the country studied [kWh/m^2]. In the case of Paris, 106 kWh/m^2 for residential heating consumption according to EDF.

Or

$$E_{H,2} = A_P \cdot N_{city} \cdot E_{H,avg} \qquad \text{Eq. 2}$$

Where:
$E_{H,2}$ = energy consumption of buildings in terms of heat [kWh]
A_P = surface area of the business park [m^2],
N_{city} = average number of storeys in the city [-],
$E_{H,avg}$ = average consumption of heat or cooling per m^2 in the country studied [kWh/m^2]. In the case of Bordeaux, 106.0 kWh/m^2 for residential heating consumption according to EDF.

According to "le panorama du parc immobilier français" published by Caisse des Dépôts, it has been assumed that the average number of floors per dwelling is 2.00.

In the case of Berlin, according to the "Urban Structural density 2019" published by the Environmental Atlas Berlin, the average number of floors per building is 2.97 and according to the article "Key data on energy consumption and heat in Germany" published by OFATE, the heating consumption of dwellings

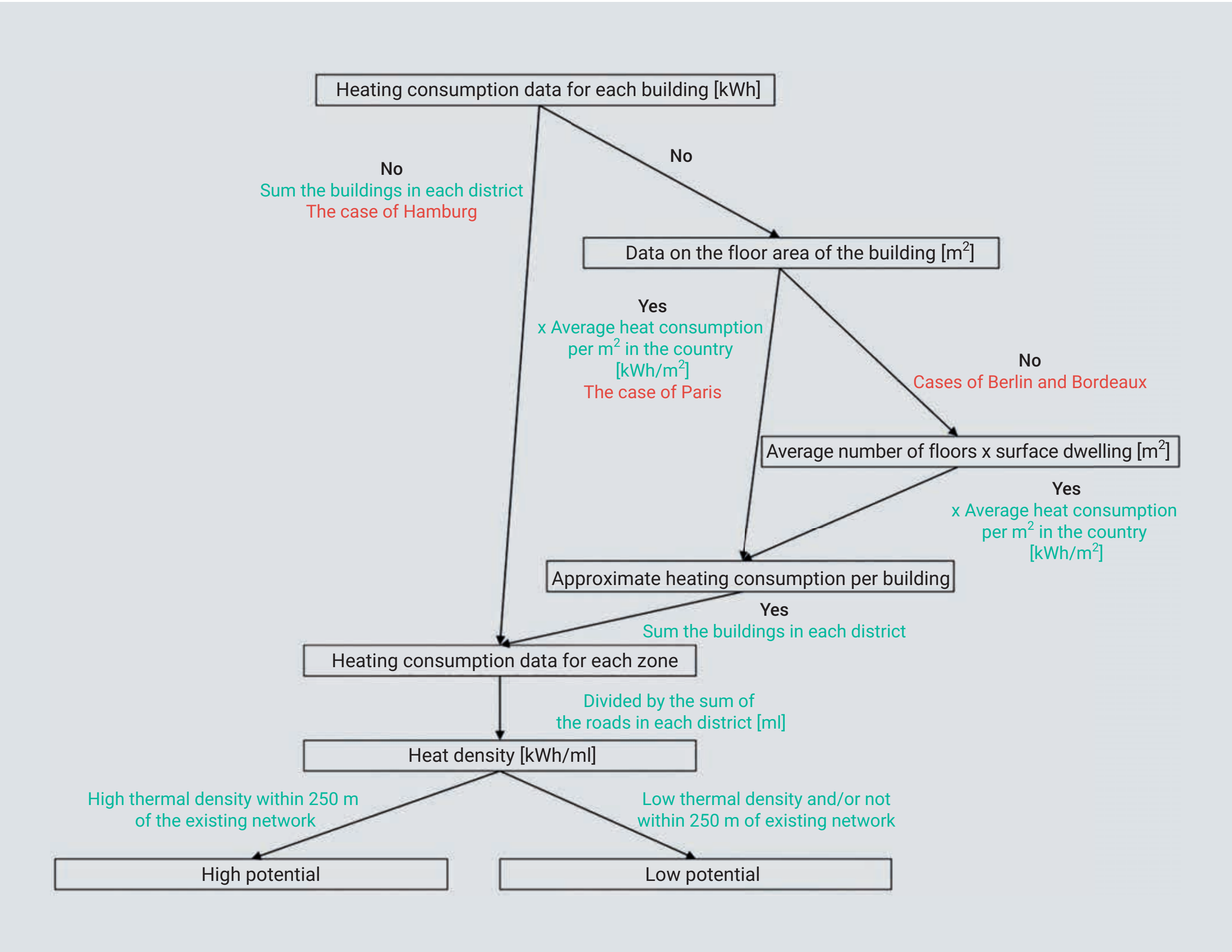

Figure 1. Flow-Chart of the study

in Germany is 126.5 kWh/m^2 (in 2022 after calculation).

The thermal density, a crucial indicator for assessing the viability of the project measured in [kWh/m], was calculated according to equation 3.

$$D_{th} = E_{tot}/L_{tot} \quad \text{Eq. 3}$$

Where

D_{th} = thermal Density [kWh/m],

E_{tot} = total heat energy consumption of the area [kWh],

L_{tot} = total length of the network for each area [m].

By cross-referencing the consumption data with the linear distances required for the network to be established, it is possible to calculate the energy density for each zone drawn, covering the whole of the city under study. By juxtaposing this mapping of energy densities with the layout of existing networks, a representation of areas with high development potential emerges: areas with a high thermal density and proximity to an existing network are those with the greatest growth potential, while areas with a low thermal density and/or not close to an existing network do not have high potential (Figure 1).

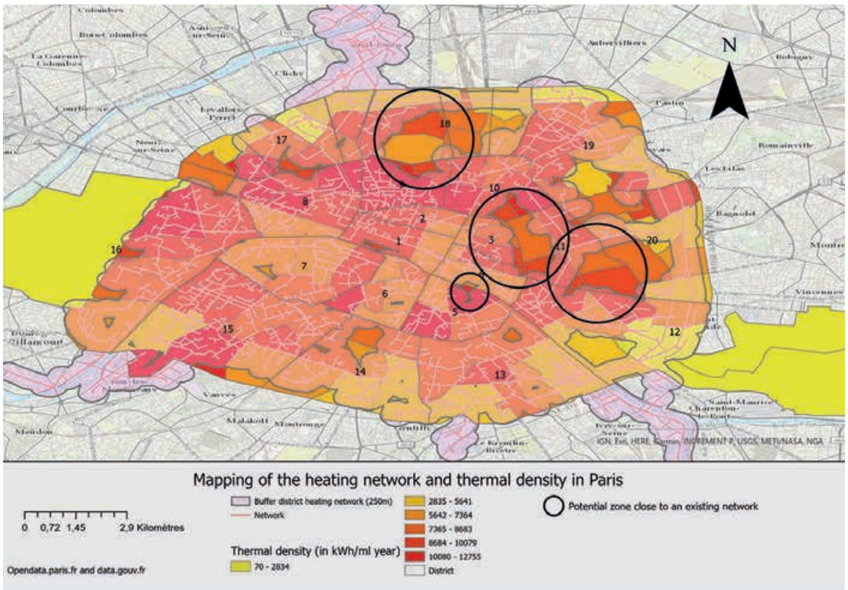

Figure 2. Mapping of the heating network and thermal density in Paris – opendata.paris.fr and data.gouv.fr with Arcgis pro[2)]

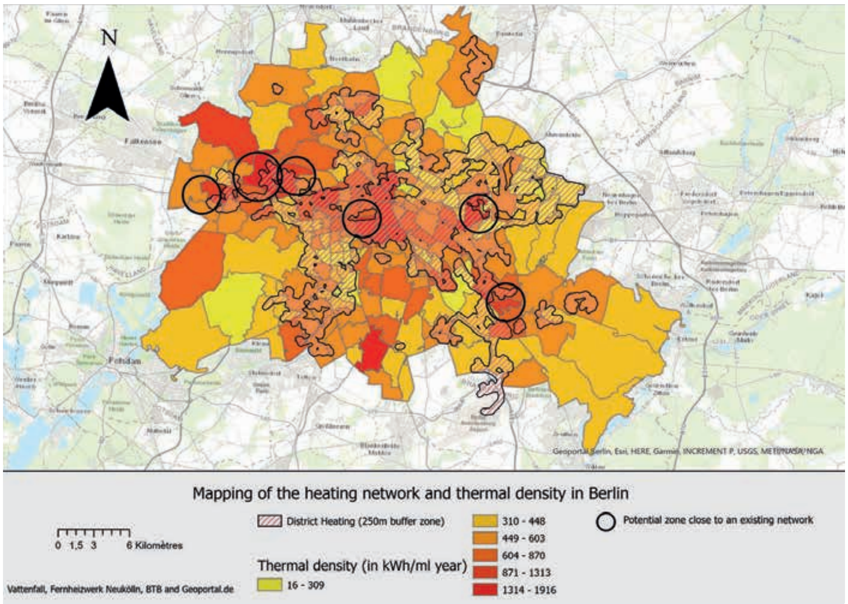

Figure 3. Mapping of the heating network and thermal density in Berlin – Vattenfall, Fernheizwerk Neukölln, BTB and Geoportal.de with Arcgis pro[3)]

The results of the study

Results for the capitals Paris and Berlin

The current heating network covers all 20 arrondissements in Paris, but the rate of connection varies considerably. The 1st, 2nd, 4th, 7th, 13th and 15th arrondissements have a high connection rate, with more than 30% of their areas connected. On the other hand, the 11th, 17th, 18th and 20th arrondissements have a low connection rate, with less than 10% connected. Although the location of the physical network varies in these boroughs, it is clear that expansion and densification of the network are emerging as major development axes.

Figure 2 shows the existing network and the thermal densities in the different districts of Paris. It can be seen that four locations close to the existing network should be connected: in the 5th arrondissement (Saint-Victor (hypothetical network length: 10.7 km)), in the 3rd and 11th arrondissements (République Saint Ambroise (hypothetical network length:26.0 km), Château d'eau Lancry (hypothetical network length: 16.1 km), Bastille (hypothetical network length: 21.5 km), Faubourg du Temple (hypothetical network length: 10.7 km), in the 18th arrondissement (Clignancourt Jules Joffrin (hypothetical network length: 23.9 km), Amiraux (hypothetical network length: 11.0 km),

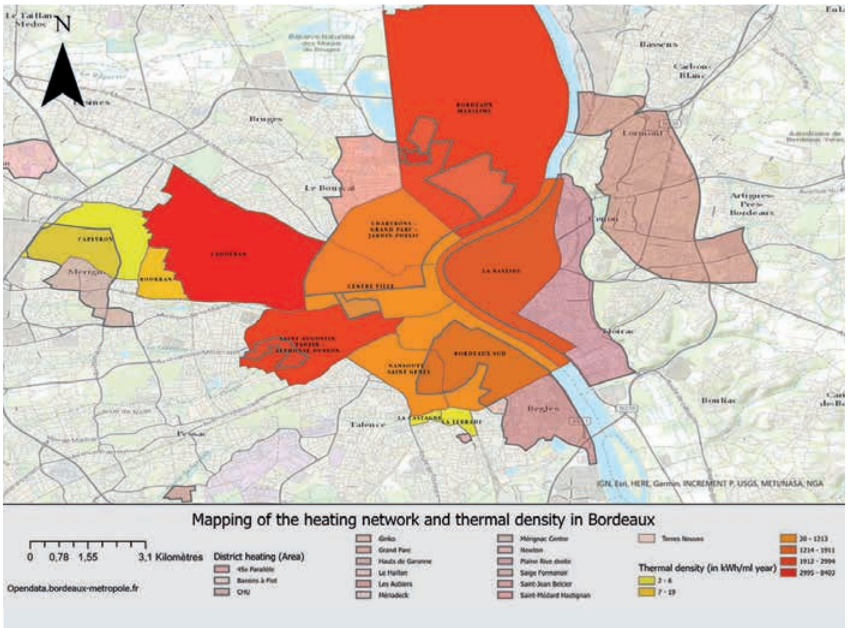

Figure 4. Mapping of the cooling network and thermal density in Bordeaux – Opendata.bordeaux-metropole.fr with Arcgis pro[4]

Goutte d'or – Château rouge (hypothetical network length: 16,483 m) and in the 20th arrondissement (Nation Alexandre Dumas (hypothetical network length: 19.3 km), Père Lachaise (hypothetical network length: 16.2 km). The least attractive places to set up a network are the 16th and 12th arrondissements.

In Berlin, extensive district heating networks cover large areas of the city centre, including the S-Bahn ring area with over 50% coverage. These networks also extend to the eastern part of Steglitz-Zehlendorf, through Lichtenberg to Marzahn-Hellersdorf, as well as to Neukölln and the western part of Treptow-Köpenick, including Adlershof.

Figure 3 illustrates the layout of the existing network and the thermal densities distributed across the various districts of Berlin. It is particularly noteworthy that, according to the map in Figure 3, at least six localities located close to the current network should be connected. These locations correspond to postcodes 13599 (hypothetical network lengths: 203,754 m), 13581 (hypothetical network length: 232.1 km), 10785 (hypothetical network length: 244.5 km), 13629 (hypothetical network length: 223.7 km), 10365 (hypothetical network length: 276.1 km) and 12439 (hypothetical network length: 153.1 km). These locations therefore have a high potential for network connection.

Results in Seaport-Metropoles Bordeaux and Hamburg

In its current form, the heating network extends to virtually every district in Bordeaux, except three: Caudéran, La Castagne and La Ferrade. Figure 4 shows the existing network and the heating densities in the various districts of Bordeaux. There are three areas close to the existing network that should be connected: Bordeaux maritime (hypothetical network length: 161.7 km), Cauderan (hypothetical network length: 124.8 km) and Saint Augustin Tauzin Alphonse Dupeux (hypothetical network length: 85.4 km).

[2] Data from: Mapping of the Parisian urban heat network CPCU: data.gouv.fr, modified on June 26, 2018, kml, available at: https://www.data.gouv.fr/fr/datasets/cartographie-du-reseau-parisien-de-chaleur-urbaine-cpcu-1/, Neighborhood councils, modified on August 16, 2023, shapefile, available at: https://opendata.paris.fr/explore/dataset/conseils-quartiers/information/?location=12,48.85889,2.34692&basemap=jawg.streets, Building volume: opendata.paris, modified on August 10, 2023, shapefile, available at: https://opendata.paris.fr/explore/dataset/volumesbatisparis/information/, Road sections: opendata.paris, modified on August 14, 2023, shapefile, available at: https://opendata.paris.fr/explore/dataset/troncon_voie/information/?location=16,48.87269,2.33808&basemap=jawg.streets, Neighborhood: opendata.paris,

[3] Data from : Heat network mapping: Geoportal.de, WFS, Published on May 15, 2020, available at: https://www.geoportal.de/Info/a7e567f4-cb79-476e-947c-30219209865d, Building volume: Daten.odis-berlin.de, shapefile, Published on June 30, 2016, available at: https://daten.odis-berlin.de/de/dataset/gebaeude/, Road section: Daten.odis-berlin.de, shapefile, Published on July 16, 2020, available at: https://daten.odis-berlin.de/de/dataset/strassenflaechen/ Neighborhood: Daten.odis-berlin.de, Berlin postal code areas: Daten.odis-berlin, shapefile, Published on October 1, 2019, available at: https://daten.odis-berlin.de/de/dataset/plz/

[4] Data from : Urban heat network mapping: opendata.bordeaux-metropole.fr, modified on August 17, 2023, shapefile, available at: https://opendata.bordeaux-metropole.fr/explore/dataset/eg_concession_s/export/?location=12,44.88239,-0.57678&basemap=jawg.streets, Building volume: opendata.bordeaux-metropole.fr, modified on February 1, 2021, shapefile, available at: https://opendata.bordeaux-metropole.fr/explore/dataset/to_bati_s/information/?location=15,44.82251,-0.56583&basemap=jawg.streets, Road sections: opendata.bordeaux-metropole.fr, modified on August 17, 2023, shapefile, available at: https://opendata.bordeaux-metropole.fr/explore/dataset/fv_tronc_l/information/?location=15,44.86874,-0.60468&basemap=jawg.streets, Neighborhood: opendata.bordeaux-metropole.fr, modified on August 17, 2023, shapefile, available at: https://opendata.bordeaux-metropole.fr/explore/dataset/se_quart_s/information/?location=12,44.83055,-0.60047&basemap=jawg.streets

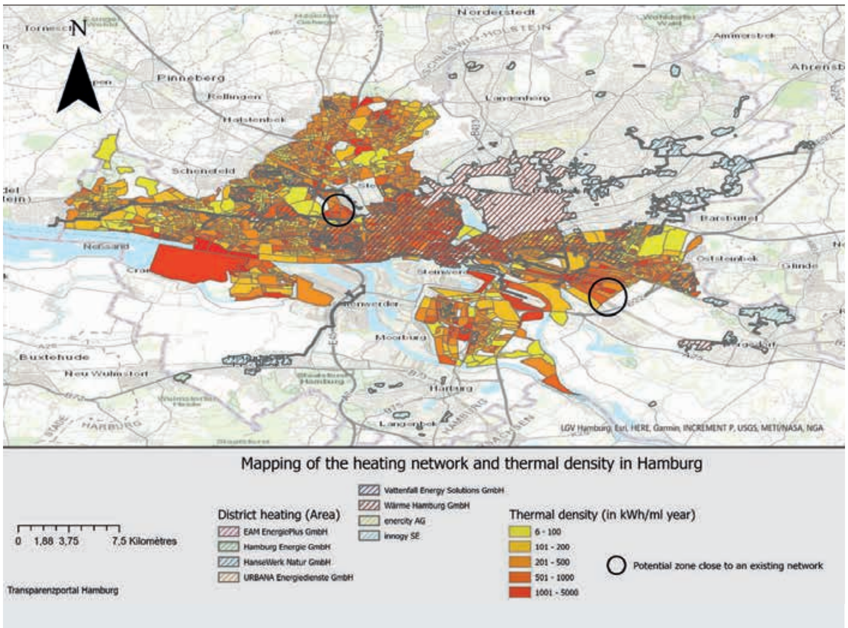

Figure 5. Mapping of the heating network and thermal density in Hamburg – Transparenzportal Hamburg with Arcgis pro[5)]

Bordeaux maritime and Saint Augustin Tauzin Alphonse Dupeux already have heating networks: Ginko, Bassins à flot and Grand Parc for Saint Augustin Tauzin Alphonse Dupeux and Centre hospitalier universitaire (CHU) for Bordeaux maritime. However, these networks do not cover all of these districts. It would therefore be worthwhile extending the networks to meet the heating needs of local residents.

In the north, south and west of Hamburg, the network does not seem to cover these localities. Figure 5 shows the existing network and the heating densities in the various districts of Hamburg. There are two areas close to the existing network that should be connected: Hamburg-Bahrenfeld (hypothetical network length: 116.2 km) and Billbrook (hypothetical network length: 182.6 km).

Critical analysis and outlook

During this study, some data could not be found in geographic file format, such as the location of thermal energy production facilities in Berlin, Paris and Bordeaux, or the mapping of the district cooling networks in Berlin, Hamburg and Bordeaux, or the consumption of heating and air conditioning. This lack of data was compensated for by bibliographical research into the various players involved in the district heating and cooling networks in each city, so that the study could continue. In addition, some of the data sets were published some time ago and have not been updated since, which reduces the accuracy and reliability of the study. On the other hand, this study tends to be as close to reality as possible. The lack of data on heating and cooling consumption by zone has been compensated for by formulas that allow the network deployment study to continue. These formulas are intended to be as close to reality as possible. However, it would be interesting to get closer to the organisations (town halls, companies, etc.) in charge of these data (consumption) to carry out more reliable studies.

In order to refine the assessment of areas with potential, it is vital to consider the diversity of buildings and the functions they fulfil. It becomes crucial to distinguish, for example, between older buildings and more recent constructions, with particular emphasis on buildings classified as energy slums. For example, the old buildings nestling in the Marais district: the question is whether these buildings are suitable for air-conditioning systems.

In addition, the average heating and cooling consumption per square meter for each city was used. However, it should be noted that heating and cooling consumption in Paris is significantly higher than in Bordeaux. Consequently, it would be beneficial to obtain specific data on heating consumption in Paris, Bordeaux and Berlin in order to improve the accuracy of future analysis.

Finally, an essential phase of this process involves identifying land that could be used for future renewable energy production facilities. The aim is to meet the region's energy needs, taking into account the specific characteristics of each ar-

5) Data from: Thermal cadastre of Hamburg energy production facilities: Transparenzportal Hamburg, shapefile, published on July 8, 2023, available at: https://suche.transparenz.hamburg.de/dataset/waermekataster-energieerzeugungsanlagen-hamburg7, Thermal cadastre of the region with Hamburg heat network: Transparenzportal Hamburg, shapefile, published on July 8, 2023, available at: https://suche.transparenz.hamburg.de/dataset/waermekataster-gebiet-mit-waermenetz-hamburg7, Heat demand: Transparenzportal Hamburg, WFS, Published on July 8, 2023, available at: https://suche.transparenz.hamburg.de/dataset/waermekataster-waermebedarf-hamburg9, Road section: Transparenzportal Hamburg, WFS, published on July 10, 2023, available at: https://suche.transparenz.hamburg.de/dataset/landesgrundbesitzverzeichnis-hamburg24, Hypothetical heat network: Metaver, Geojson, published in September 2018, available at: https://metaver.de/trefferanzeige?cmd=doShowDocument&docuuid=D72E73FB-97A0-45DD-BE51-DE9C4EB5C4C2

ea, whether in terms of heating, cooling or other particular energy services.

Conclusion

The transition to more sustainable energy sources is a necessity in the face of today's climate challenges. District heating and cooling systems play a crucial role in this transition, particularly in densely populated urban areas. In these urban contexts, district heating and cooling systems are emerging as promising technological solutions, enabling better integration of renewable energy sources.

In France and Germany, the potential for integrating renewable energies into networks is immense. Sources such as geothermal energy, solar thermal energy, industrial heat recovery and wastewater heat recovery can all be harmoniously integrated. Cities like Paris and Bordeaux in France, or Berlin and Hamburg in Germany, each have their own energy profile and distinct renewable resources. When setting up these networks, it is essential to consider the most suitable energy sources and technologies to not only minimise carbon emissions, but also enhance the robustness of urban energy infrastructures in the face of the vagaries of energy markets and potential supply disruptions.

However, despite this enormous potential, a number of challenges remain. High initial costs, the need for suitable infrastructure, and the variability of some renewable energy sources call for innovative solutions and careful planning.

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T-branch with Clip-Flex shroud system

Shrouds for Flexible Polymer Pipe Systems in Heating Networks: the Requirements and Solutions

In recent years, flexible polymer pipe systems have become an integral part of district heating networks. The reduction in network temperatures in conjunction with the integration of renewable energy sources is acting as a long-term catalyst for this trend. However, the use of pre-insulated PE-Xa pipe systems can only be successful in the long term if the shroud system, often the weakest link in the chain, also consistently meets design and construction requirements in practice.

The low carbon heating transition must be implemented in existing buildings, otherwise these ambitious targets can never be achieved. The development and expansion of district heating networks therefore requires a significant increase in the number of stakeholders involved at every stage – from project development and technical planning, to pipework specialists and installers to local authorities, and energy supply companies, and last but not least main contractors.

When selecting materials for heating networks, opinions still tend to differ. It is clear that the expansion of district heating for large transport and main pipelines requires the use of steel pipes and involves the highly specialised knowledge of welding specialists, as well as increased installation capacities in the network. However, at a more local level, the use of polymer pipe systems is often technically feasible as well as beneficial. Planning and installation is much easier and quicker, while the use of pre-insulated PE-Xa pipes is cheaper in many cases and ultimately more economical. These solutions have become widespread in recent years, especially in new-build projects, as demonstrated by a large number of successfully implemented projects.

Pipes prioritised over shroud systems

When planning polymer networks, the focus has previously been almost exclusively on the pipes. The hydraulic design and a reduction in heat losses, e.g. through increased insulation, are usually the focus which is of course important. Nevertheless, the overall system is only as good as its supposed weakest link – the shroud system for the insulation of joints and branches. As network operators, energy supply companies rightly impose strict requirements on security of supply. The shrouds must also meet these requirements. In this context, installation, i.e. handling on the construction sites, is the real litmus test. It is important that the shrouds are durable and fully tailored to the various application situations.

Among differing competing technologies, the clip system consisting of two half shells has become widely accepted and used over the past decade. The joint between the upper and lower parts of the shroud is bonded using a special plastic adhesive. The necessary pressure is continuously applied by clamps or clips, similar to the fastening on a ski boot. A special seal on the pipe inlets ensures that water cannot get in and stops the interior from becoming damp (Figure 1).

Special requirements for polymer pipe systems

The financial benefit of using flexible pipe systems partly arises from the use of coils. Pipeline sections of various lengths can be quickly installed without any additional connections between the branches, saving both time and materials. However, this means that angle deviations often occur when installing the pipe in the shroud body. These have resulted in special requirements for the shroud seal for polymer pipes which do not apply for steel pipes as angle deviations do not occur. According to DIN EN 489, which is well-known in the steel pipe sector, the shroud seal must be certified at a water column of 3 m and 0.3 bar. For shrouds in the polymer segment, this means that the manufacturer must define this prerequisite as a special test requirement to adequately reflect the stresses that occur in practice.

Another aspect to consider in the installation of polymer pipes is that permanent compression joints are widely used to connect PE-Xa pipes, e.g. the Rehau compression sleeve system. This technology does not require an additional sealing element, is extremely robust, can be inspected visually and has proven to be effective in many different areas of use for 35 years. A modular fitting is used for branches with unusual size combinations. In this instance, the shroud would require additional space for installation.

New Clip-Flex system solution

Based on extensive experience and the special requirements outlined above, Rehau has further developed its existing clip shroud technology. The result is an innovative, user-friendly solution that combines a wide range of special features. The crucial structural element is a ball joint between the two halves of the shroud and the joint which allows an angle deviation into the shroud itself. The seal is created by multiple lip seals made of extremely durable TPE. Sealing rings are inte-

Figure 1. Pipeline with branch a) before and b) after the shrouds are sealed

grated into the joint, which can also offset any angle deviation, i.e. a total of 22.5° per joint or up to 45° over the entire component in the pipeline, under loads with external water pressure of 0.3 bar (Figure 2). These shrouds are also now compatible with an outer piper diameter of up to 250 mm, compared to 182 mm previously. This means that all Rehau pipe systems can be accommodated, including carrier pipes with a size of 160 mm (Figure 3).

The space for making joints is now 20% larger. This means that any combination of sizes can be safely accommodated with a modular fitting and easily processed using the compression sleeve tool. Individual additional size reductions can also be integrated within the shroud itself if required.

This modular structure of the half shells and joints results in a 30% smaller pack size. In combination with the use of high-quality recycled material in the shroud injection moulding process, the carbon footprint in production and transport is also significantly reduced.

Figure 2. Clip-Flex with clear angle

Figure 3. Clip-Flex L-shrouds with deviation during pipe installation 160/250 mm pipe joint

Outlook

District heating design will pave the way for the increased use of polymer pipe systems in the years ahead. In addition to individual networks, the focus will increasingly be on their application in hybrid and secondary networks. It is more important than ever to think in terms of overall systems and consider this aspect when selecting materials. The polymer carrier pipe is primarily designed to be durable at temperatures of up to 90 °C to ensure that existing buildings that have not yet been renovated can be supplied from the start. Another aspect is the longitudinal water tightness of the pipes as a prerequisite for permanent, efficient network operation. And, last but not least, the jointing technique between pipe and fittings which should be of particular importance for key decision-makers for system certification. Manufacturers such as Rehau are investing in ongoing product development and capacity expansion in order to make a significant impact to the decarbonisation of heat supply using polymer heating networks.

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New Danish Measures for Reducing Legionella in Domestic Hot Water Installations

Through an interdisciplinary project collaboration with among others Danish Technological Institute and Statens Serum Institut, a major study about Legionella in domestic hot water installations was carried out. Besides, three solutions aiming at reducing the occurrence of the deadly bacteria Legionella in installations and taps were developed and demonstrated.

Despite the generally good quality of Danish drinking water, Denmark has – compared to other European countries – a relatively high frequency of incidences of Legionnaires' disease caused by the bacterium Legionella. Moreover, the number of incidences has been increasing for some years. It is generally recognised that the use of temperatures that are too low in the domestic hot water can contribute to this. The low temperature allows the growth of Legionella bacteria, and the bacteria may spread to humans in the form of small water particles (aerosols) from e.g. showers.

Approximately two third of the Danish homes – and the associated domestic hot water – are heated with district heating. As for the rest of the households, heat pumps are gaining ground to a considerable extent. With regard to energy efficiency and the possibilities of using alternative energy, it is important for both energy systems that the water temperatures are as low as possible. There is thus a significant temperature-related dilemma around ensuring legionella-proof domestic water installations in relation to the desire to save energy and reduce the climate footprint.

Through an interdisciplinary collaboration co-financed by EUDP (Danish Energy Technology Development and Demonstration Programme), the project "Legionella protection and energy efficiency for installations and supply" has been implemented and completed. The project includes partly the implementation of a major study on previous investigations and requirements for Legionella in domestic hot water, partly the development and demonstration of three solutions for the domestic hot water installations with a view to reducing Legionella and the incidences of Legionnaires' disease.

The project partners were Danish Technological Institute, Statens Serum Institut (SSI, under the auspices of the Danish Ministry of Health), VIA University College, the producers Metro-Therm A/S and Danish Clean Water, Fredericia Fjernvarme representing Danish district heating companies, the large Danish housing company KAB (representing 70,000 homes) and the Project Office/Region Zealand representing Danish hospitals.

The study was based on a major literature search and covered Danish and international literature/sources, and it was followed up by contacts/Teams meetings with selected knowledge and research centers. The study included an examination of the influence parameters affecting the spread, growth and reduction of Legionella, as well as authority requirements, standards and guidelines. Among other things, the study showed that due to biofilm the temperature requirements for protection against Legionella are often underestimated, just as the Danish temperature requirements are low compared to other countries. Furthermore, it was found that even lower temperatures are sometimes used in practice in the installations.

The study also leads to the following conclusions:

- It is generally agreed that Legionella pneumophila develops at temperatures higher than 20-25 °C and lower than 45-50 °C. On the other hand, due to e.g. biofilm formation, there is a considerable uncertainty when it comes to the temperatures required for reduction of Legionella – and for how long time the temperatures must be present.
- In Denmark and abroad, Legionella prevention is primarily handled by using an appropriate temperature for the domestic hot water. However, this is very challenging for energy efficiency, climate footprint and running costs as the necessary water temperature to avoid Legionella must be 50 °C or higher, while the comfort requirement is only 45 °C.
- The temperature is the most important influencing parameter for the development and reduction of

Legionella in the installations, but several other parameters come into play such as water flow conditions, water quality, pressure, affected materials and presence of biofilm. However, the study showed that the knowledge of the conditions influencing the growth and reduction of Legionella is often relatively poorly founded or unclearly documented, e.g. it has not been clarified how temperature and flow conditions play a role together.

- Nationally and internationally, there is a relatively limited regulatory encouragement to search for alternatives to temperature protection against Legionella.
- The new EU drinking water directive has increased the focus on Legionella and on the risk assessment of water installations.

The conclusion of the study was that because of the significant challenges between protection against Legionella in domestic hot water and achieving high energy efficiency and low climate footprints it is very important to focus on all potential opportunities for improvements, just as it is important that new knowledge and insight into the problems is ensured.

The three developed and demonstrated initiatives in the project to reduce the presence of Legionella in domestic hot water installations include:

- A risk pilot assessment tool for Legionella in domestic hot water installations (Danish Technological Institute). The tool is based on a recognised method through adaptation of the found influence parameters on Legionella in domestic hot water installations with a view to making it usable in practice. The tool may contribute to an improved clarification of both existing and new drinking water installations.
- An electric booster unit ensures temperature monitoring and optimal control of the domestic water installation based on knowledge of Legionella growth and reduction (Metro-Therm). The solution will be able to support future adaptation and development of products for the increased temperature challenge for protection against Legionella.
- A new setup for biocide dosing with hypochlorous acid (Neuthox, Danish Clean Water), which is environmentally friendly and allows legionella protection at a lower water temperature, i.e. corresponding to the comfort needs. The project showed that it is possible to reduce high legionella germ counts to a tolerable level and to be able to maintain it. Hence, the solution will be able to provide clear advantages in terms of reducing energy and climate footprints and is proposed to be included formally in the Danish authority requirements, provided that specific documentation requirements for its efficiency in the whole installation are met.

The project is documented through a number of professional reports in Danish as well as through an English final report summary that can be found under https://www.teknologisk.dk/_/media/87227_EUDP%20Jnr64020-1099%20Legionellasikring%20-%20Final%20report%2020230228.pdf.

www.dti.dk

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The generator from Danish Clean Water disinfects drinking water efficiently, killing dangerous bacteria such as Legionella

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