Perspectives on **key digitalization challenges** within the **district energy sector**

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Abstract

In November 2023, the final report from the International Energy Agency (IEA) District Heating and Cooling (DHC) task share project Digitalisation of District Heating and Cooling was published. The aim of the project was promoting the opportunities arising from integrating digital processes into different parts of DHC systems and end-user heating installations. It also collected use cases of already available digitalization solutions to demonstrate the impact digital solutions have on the system operation, both on existing systems going through a modernization cycle as well as in new systems. The consortium behind the project was carefully chosen to include the key research institutions, universities and digital solution providers in the DHC sector to ensure the most holistic view on the current market status, as well as for giving collective perspective on the key challenges for the future development of digital solutions within the district energy sector. This paper gives a digital solution provider perspective on the identified challenges within the report, "*Guidebook for the Digitalisation of District Heating: Transforming Heat Networks for a Sustainable Future*"[1].

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Introduction

As thermal demands of buildings can generally be fulfilled by low quality energy, meaning low temperature energy, buildings have the potential to play a key role in decarbonizing the energy supply. However, realizing this potential requires having an infrastructure in place that can enable long-term decoupling of thermal demand and generation. Such decoupling facilitates the transition from dispatchable fuels towards diverse time varying alternatives, such as fluctuating renewables, waste heat and ambient heat. This enabling infrastructure is an old, but continuously evolving, concept called district energy. The mechanical and philosophical nature of the district energy ideology have been evolving for over a century, with major developments branded as the generations of district heating[2-5] and cooling[6].

It is commonly accepted that district energy is an infrastructure with the potential to be the backbone of the decarbonized future. However, for district energy to be part of the future:

- We need it to be robust, yet flexible.
- We need it to be reliable and secure, yet open and supportive to other sectors.
- We need it to be green, yet sustainable.
- We need it to be local, yet it should act global.
- We need it to be widespread, yet affordable.

To be able to live up to these expectations, it is essential to embrace digital solutions and fully integrate these solutions into the district energy concept, because current best practices are insufficient to realize the potential of the technology.

The system complexities are exploding, due to ever growing networks, increased focus on multi-source operation, and increased coupling points with the other energy sectors. This increasing complexity demands embracing of digital solutions to ensure stable and effective system operation as well as to achieve end-to-end system optimization.

Digitalization is emerging as a major development driver for district energy systems. It will have a profound impact on the whole concept of district energy as it has the potential to touch essentially all aspects of the thermal supply system. Where its interactions range from:

- the overall energy system,
- the thermal generation for the district energy infrastructure,
- the distribution system,
- the end-user system interface units,
- the operation of the building thermal installations,
- as well as interacting with end-users to ensure that their thermal requirements are met.

All these interactions can further be tied together to create an end-to-end optimization solution that ensures optimal thermal generation is achieved, utilizing the appropriate mix of input energy in relation to the overall energy system.

As digitalization of the infrastructure is widespread, complex and involves many stakeholders, there are numerous challenges that must be overcome before the full potential of digitalization can be realized. In the "*Guidebook for the Digitalisation of District Heating: Transforming Heat Networks for a Sustainable Future*", the following seven key challenges are identified:

1. Heterogeneity of DHC systems
2. Lack of standards for DHC
3. Vendor-lock in and interoperability
4. Need for robust and resilient control architectures
5. GDPR compliance
6. Safety and security of IT systems
7. Lack of (labelled) reference datasets and benchmarks

In the following sections, the author gives his perspectives on these challenges with the solutions offered by Danfoss in mind.

Challenge 1:
Heterogeneity of DHC systems

One of the many interesting aspects of the district energy sector is its local uniqueness and operation. The uniqueness of each system originates from the varying local conditions, due to climate, geographical features, network layouts, available energy sources, local building standards, building district energy interface units and building utilization. On top of all the location-specific aspects, the existing systems can be many decades old and at varying levels of renovation and modernization. Furthermore, most systems are locally operated, under the direction of the local government or community.

All the above results in a very fragmented market, which creates challenges for the development of a standardized digital solution that can fit all systems and agendas.

Any digitalization solution provider needs to recognize and accept that while the fundamental purpose of all district energy systems is the same, to fulfill heating or cooling demands, they have different needs. To address this, Danfoss Climate Solutions adopted a modular approach, where the key elements of the supply system are addressed in specific modules, which can be linked together for unlocking optimization potential across the supply chain.

Danfoss Climate Solutions digital offerings for district energy systems include:

- **Leanheat® Buildings** – For optimizing the building operation and creating building specific demand forecasts.
- **Leanheat® Network** – For optimizing the distribution network design and operation.
- **Leanheat® Production** – For optimizing the thermal generation and interaction with the wider energy system.
- **Leanheat® Monitor** – For enabling remote monitoring, control and optimization of the district energy system.
- **Leanheat® Forecasting** - Predictive AI based solution for demand and flow temperature forecasting.
- **Danfoss Titan™** – A digital twin of substations for continuous commissioning and actionable insights for network optimization.

Challenge 2:
Lack of standards for DHC

The challenge at hand revolves around the absence of standards in the digitalization of DHC. The sector has historically been decentralized, often initiated by enthusiastic local champions. While the local nature of DHC is a source of strength, it introduces the risk of ad-hoc, non-standardized solutions, including units, data communication standards and even local terminology for components. Describing DHC networks itself becomes a challenge due to the lack of a standardized vocabulary, a point emphasized in the paper, "Vocabulary for the Fourth Generation of District Heating and Cooling"[7].

Recognizing the pivotal role of a standardized vocabulary and data protocols in accelerating digitalization within DHC, the sector has established a digitalization standardization group within the DHC+ research platform, an initiative strongly supported by Danfoss. Like the journey of the power sector, DHC is undergoing a process wherein a standardized protocol is to be developed, agreed upon and implemented across the industry.

In this pursuit, the importance of data semantics and ontology cannot be overstated. The semantic understanding of data ensures that information is not only standardized in format but also in meaning. Establishing a shared ontology for the DHC sector enables a common understanding of terms and relationships, facilitating interoperability and consistent interpretation of data across diverse systems. This semantic clarity is essential for overcoming the challenges posed by diverse local dialects within the sector.

To bolster this initiative, Danfoss is actively engaged in supporting the sector. Until a standardized protocol is established, the focus is on providing robust support, including features like automatic unit conversion, crucial for averting data errors.

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Challenge 3:
Vendor-lock in and interoperability

Digitalizing district energy systems faces a significant obstacle in the form of vendor-lock in and limited interoperability. The historical fragmentation and absence of standardized digitalization practices in DHC have led to the prevalence of "built-to-order" solutions. These solutions are custom-designed for individual utilities, tailored to meet location-specific requirements. Unfortunately, the localized nature of these designs tends to hinder interoperability with third-party solutions, as they often employ proprietary data standards and storage methods, resulting in a state of vendor-lock in.

Breaking free from this vendor-lock in is crucial to fostering collaboration and enabling solutions from various vendors to seamlessly work together. Danfoss recognizes this imperative and is actively engaged in developing a modular-based offering through the Danfoss Leanheat® platform. This platform addresses key components of the heat supply system, including buildings, distribution networks and production plants.

However, the journey doesn't stop there. Localized DHC systems often necessitate tailor-made add-ons to meet unique needs. Therefore, the Danfoss goal is to create an ecosystem where diverse modules, addressing specific local requirements, seamlessly integrate into the broader Leanheat® platform, promoting adaptability and scalability in district energy digitalization. By enabling integration with third-party solutions, Leanheat® offers great digitalization flexibility to district heating and cooling utilities.

By advancing towards modular, interoperable solutions, we pave the way for a more collaborative and future-proof district energy landscape, where innovation thrives, and local needs are met through a harmonized digital framework.

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Challenge 4:
Need for robust and resilient control architectures

District energy stands out as a robust, reliable and resilient energy infrastructure, a fact extensively discussed in[8]. Positioned as a pivotal solution, district energy empowers countries to achieve energy independence, while ensuring affordable energy access for their population. As the sector moves towards digitalization, a crucial consideration is maintaining the robustness and reliability of these systems, safeguarding against potential risks posed by cyberwarfare, cyberterrorism and cybercriminal activities.

Digitalization, though instrumental in ensuring stable and affordable heating and cooling supply from a diverse range of local renewable energy sources, should not inadvertently introduce vulnerabilities. To mitigate these risks, it is imperative that future digital solutions are not only built on robust and resilient architectures, but also incorporate fallback options to address worst-case scenarios.

At Danfoss, our approach to developing solutions is rooted in decades of experience and knowledge garnered through active involvement in the DHC sector. Leveraging this extensive knowledge of components, applications and the overall supply system, we are uniquely positioned to design control infrastructures with resilience and local fallback redundancy at their core. By prioritizing the development of digital solutions that anticipate and address potential threats, we contribute to ensuring the continued dependability and resilience of district energy systems in the face of an evolving digital landscape.

In the pursuit of robust and resilient control architectures for district energy digitalization, Danfoss Leanheat® solutions are designed based on a layered approach. The Leanheat® suite, in combination with on-site controllers, offers a comprehensive range of functionalities, including monitoring, setting management and optimization solutions. When applicable, these features are orchestrated through cloud platforms and effectively communicated to local controllers, ensuring a cohesive and integrated system under normal conditions as well in case of unexpected disruptions.

For example, the Danfoss Leanheat® Building, designed to operate at the building level, employs Model Predictive Control (MPC), offering a digital solution that not only enhances energy efficiency but also introduces grid flexibility and supports demand response mechanisms. Crucially, this layered approach ensures a robust system by minimizing the impact of communication failures. In instances of communication breakdowns, the local control demonstrates its full capability to operate the respective subsystems in a standalone mode. The resilience of the standalone operation has been proven through decades of operation in the field, showcasing the platform's ability to maintain control and functionality even under challenging conditions.

The Leanheat® Suite

Leanheat® Production	Leanheat® Network
Leanheat® Monitor	Leanheat® Building

Challenge 5:
GDPR compliance

When considering digitalization of infrastructures like DHC, it is important to understand the aims and goals of the GDPR regulation, and where it applies. The aim is to ensure protection of natural persons from exploitation of their personal identifiable data. The regulation does not restrict the use and processing of personal data for the purpose of fulfilling societal functions, where energy supply infrastructure can be argued to fall under, as long as it is proportionally balanced against the fundamental rights of an individual's personal data. An example of valid utilization of personal identifiable data is when it is for a) fulfilment of legal contracts, b) fulfilling legal obligations or c) performing a catalogue case.

a) A contractual case is, for example, for billing of energy consumption.

b) An obligation case covers mandatory data collection and processing for fulfilling legal requirements.

c) A catalogue cases covers specified and regulated data usage cases. The dataset catalog offers comprehensive descriptions and intelligent tagging, offering precise definitions on the lawful utilization of information. It follows that only the amount of personal data or the type of personal data that is necessary to fulfill the case is collected, as the principle of data minimization applies.

Additionally, data collection and processing are allowed for nonregulated data usage once a revokable consent from the owner is granted.

In respect to infrastructures like the DHC, the GDPR becomes relevant in situations where data is being collected and is to be used for purposes other than those that fall under legal contracts or obligations, and the data collection occurs close enough to an individual user that they can be identified directly based on the collected data, or through a combination of other information or technical resources. However, paragraph 1 of Article 6 of the GDPR lists situations where data processing is to be considered lawful. Of the listed points it is particularly points e) and f), see below, that are relevant for data processing in district energy systems:

(e) processing is necessary for the performance of a task carried out in the public interest or in the exercise of official authority vested in the controller;

(f) processing is necessary for the purposes of the legitimate interests pursued by the controller or by a third party (…).

From these points it can be argued that the public advantage from data reading and processing used for achieving energy efficiency and climate benefits are strong enough for falling under the umbrella of lawful data processing as stated in Article 6 of the GDPR[9].

To ensure a fair relationship between users and data holders, the EU has developed a data regulation called the Data Act. The Data Act came into force January 11, 2024, and becomes applicable September 12, 2025. As the Data Act covers both personal and non-personal data, it is a complementary regulation to the GDPR. The Data Act is aimed at facilitating data sharing and ensuring a sustainable environment for the future development of data driven solutions, by imposing an obligation on data holders to make data available to users and third parties of the user's choice. The Data Act does not differentiate between business or consumer users when it comes to the right of sharing data. Further, the Data Act adapts rules of contract law and prevents the exploitation of contractual imbalances that hinder fair access to, and use of, data.

The Data Act further sets requirements on the manufacturers of connected products and related services, to ensure that data that is transmitted out of the product and collected is always easily and securely accessible to a user, free of charge, and in a comprehensive, structured, commonly used and machine-readable format.

This new regulation will be a stimulating driver for the future growth of digitalization solutions and has the potential to unlock new, and so far, practically unattainable, benefits. The Data Act further puts data sharing requirements on data holders when the use of data is beneficial for the public interest, which can be interpreted in the context of ensuring energy security and mitigating climate change.

Leanheat® digital solutions comply with security standards and the fundamental principles set out in Article 5 of GDPR on processing of personal data. Danfoss whole-heartedly supports the fair and sensible use of data for the purpose of realizing energy efficiency, energy security and climate benefits.

Challenge 6:
Safety and security of IT systems

With increasing threats from cyberwarfare, cyberterrorism and cybercriminal activities, software development teams need to be vigilant and be able to quickly react to emerging threats, particularly in the context of critical infrastructures like DHC systems.

Danfoss' digital solutions are built with security in mind. Security measures and considerations are incorporated into design and development from the very beginning. We consider security an integral part of the development lifecycle, ensuring that security measures are implemented at every stage, including architecture, coding, testing and deployment.

The Danfoss Security operations team serves as the first line of defense in an organization's security infrastructure. Their primary responsibility is to monitor, detect and respond to security incidents and threats in real time. They play a crucial role in identifying and mitigating potential security risks, investigating security incidents and ensuring the overall security posture of our digital solutions, which is crucial in today's cybersecurity landscape.

One important aspect of ensuring high safety and security of IT systems involves making resources available for maintaining the systems. In that respect, standardized and cloud-based solutions developed and supported by strong companies, like Danfoss, have greater access to resources to maintain the security and integrity of their systems.

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Challenge 7:

Lack of (labelled) reference datasets and benchmarks

With the significant variations from system to system, in terms of climate, geographical conditions, building demand profiles and the wide range of applicable heat sources, developing a generally representative dataset for the sector can be a challenge. However, due to the high cost associated with changing between IT systems, it would be a great benefit to have reference datasets and benchmarks as one of the parameters utilities can look towards when deciding on their future digitalization system.

Conclusions

Due to the general complexity of district energy systems, different digital solutions target different aspects of the system. Depending on the aspects that are being addressed, different challenges may be encountered. Some challenges can be considered generic, for example challenge 6: "*Safety and security of IT systems*" and challenge 4: "*Need for robust and resilient control architecture*". Others are more human, or even historically, related, for example the non-standardize vocabulary mentioned in challenge 2: "*Lack of standards for DHC*". Then there are challenges with the evolving legal environment in respect to data collection, storage and utilization, as is described in challenge 5: "*GDRP compliance*".

The local nature of district energy systems adds another level of complexity for developing digital solutions, as is addressed in challenge 1: "*Heterogeneity of DHC systems*". To overcome this issue and ensure viable scaleup of digital solutions, it is vital to have a deep fundamental understanding of the interaction between the various system components. Without an understanding of the universal physical nature of the DHC system, there is a real risk that any digital solution developed will become a local solution with minimal scaling potential. This creates the risk that the solution provider will abandon the solution, which in turn poses a risk for the DHC operator.

Challenge 3: "*Vendor-lock in and interoperability*" and challenge 7: "*Lack of (labelled) reference datasets and benchmarks*" relate to the fact that there is an inherent lock-in risk when choosing large complex solutions for critical infrastructure systems. Once digital solutions become integrated and necessary for system operation, switching from one solution provider to another becomes a practical nightmare scenario for the system operators, perhaps requiring an operational shutdown for days, if not weeks, while they change software systems. This potential dependency on a software assisted operation poses the risk of vendor lock-in, or even a monopoly situation, which must be avoided. While achieving a monopoly situation may, at a first glance, sound appealing to the solution provider, it would be detrimental for the growth and spread of the solution, and hence go against the provider's long-term interests. This risk is indirectly being countered by the new European Union Data Act, which imposes the obligation on data holders to make data available to users and third parties of the user's choice. In that sense, the Data Act will contribute to reducing the risk of vendor-lock in by ensuring that a competing solution can access the generated data and by that enable a fast transition between solutions.

At Danfoss, we acknowledge the existence of these challenges, and we are working diligently to address them in the solutions we are developing. We further foresee that cooperation with other solutions will benefit the long-term growth of the DHC digital solution business.

The author is in no doubt that the modern advancement of digital solutions is the driver of a new evolutional paradigm of the district energy concept, and we will see increased application and development of digital solutions across the heat supply chain in the years and decades to come.

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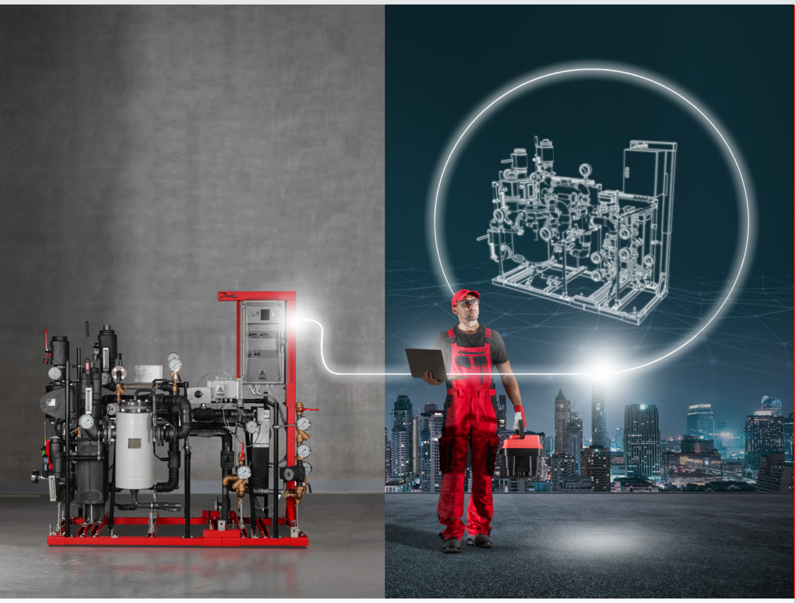

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