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Energy data: mapping, barriers and value creation

Final report of the IDASC project

August 2021

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Opsummering på dansk

Det stigende niveau af digitalisering og en stor datamængde i energisektoren muliggør øget systemfleksibilitet, reduktion af CO_2 emissioner og forbedring af energieffektivitet. Denne publikation er en del af projektet IDASC (Intelligent Data Anvendelse i Smart Cities) finansieret af Region H og indeholder en kortlægning af energidatatyper der er tilgængelige i Danmark, en analyse af barrierer til dataindsamling og -brug samt en oversigt over værdier, som energidata kan medføre. Data til denne rapport blev indsamlet gennem litteraturgennemgang og dybtgående semistrukturerede interviews foretaget med udvalgte interessenter, der beskæftiger sig med energidata. Rapporten følges af to andre leverancer: rapporten "Erfaring med at bruge datadrevne metoder i fjernvarme: Digitaliseret drift i Tingbjerg, København" og rapporten "Digitalisering af fjernvarmen - erfaringer der luner"[1].

Vores undersøgelse viser, at mange nøgleaktører stadig opfatter lovgivningsmæssige, tekniske og dataadgangsrelaterede barrierer som en hindring for effektiv indsamling og deling af energidata. Andre hyppigt nævnte barrierer er: organisatoriske, utilstrækkelig viden, utilstrækkelig datasikkerhed og kommunikation. Aspekter såsom usikkerhed om fordelene ved de forskellige initiativer, silotænkning på grund af traditionel organisering og lovgivning komplicerer også mulighederne for øget digitalisering. Disse barrierer hindrer mulighederne for at anvende data i analyser der kan afsløre potentialer for øget systemfleksibilitet, sektorkobling, implementering af vedvarende energi, reduktion af CO_2 udledning og energibesparende foranstaltninger. Beslutningsprocesserne vedrørende datastyring og facilitering af digitaliseringsinitiativer på nationalt, kommunalt og forsynings- / virksomhedsniveau skal forbedres for at tackle disse barrierer.

Vi anbefaler fjernvarme-, it- og elselskaber at samarbejde for at dele erfaringer med datahåndtering samt udarbejde og implementere skabeloner til dataaftaler og retningslinjer for lovgivningsprocesser. Vi anbefaler også at kommuner tilegner sig en strategisk tilgang til datastyring, koordinerer med ejendomsadministratorer for at identificere åbne spørgsmål og aktivere nøgleaktører (f.eks. fjernvarmeoperatørerne) for at udnytte potentialet for CO_2 reduktion samt udgiver flere åben data, hvor de er tilgængelige. Vi foreslår, at nationale enheder leverer fælles standarder for dataformater og udvikler

[1] https://issuu.com/dtudk/docs/digitalisering-af-fjernvarmen?fr=sNTBlNzQ4NjgwMg

lovgivning, der dynamisk vil følge udviklingen inden for datavidenskab, og støtter og udvikler initiativer til åben data og co-creation.

Executive summary

The growing level of digitalization and data abundance in the energy sector enable increasing system flexibility, reducing CO_2 emissions and improving energy efficiency. This report is part of the IDASC (Intelligent Data Use in Smart Cities) project financed by The Capital Region of Denmark (Region H) and contains a mapping of energy data types available in Denmark, an analysis of barriers for data collection and use and, finally, an overview of the value energy data can bring. Data for this report was collected through literature review and in-depth semi-structured interviews conducted with selected stakeholders dealing with energy data. The present report is accompanied by two other deliverables: the report "Experience of using Data-Driven Methods in District Heating: Digitalized Operation in Tingbjerg, Copenhagen" and a report in Danish, entitled "Digitalisering af fjernvarmen - erfaringer der luner" ("Digitalization of district heating").

This study demonstrates that key actors believe that legislative, technical and data access-related barriers still exist for efficient data collection and sharing. Other frequently mentioned barriers are organizational, insufficient knowledge, insufficient data security, and insufficient communication. Aspects such as uncertainty about the benefits of the various initiatives, silo mentality due to traditional organization and legislation complicate the possibilities for increased digitalization. These barriers hinder the possibilities for applying data in analyses that could reveal potentials for increased system flexibility, sector coupling, and implementation of renewables, CO_2 emission reductions and energy saving measures. The decision-making processes concerning data governance and facilitation of digitalization initiatives on the national, municipal and utility/company level need to be improved to address these barriers.

We recommend district heating and electricity operators and IT companies to collaborate in order to share experiences on data handling, as well as prepare and implement templates for data agreements and guidelines for legislative processes. We also recommend municipalities to strategically approach data governance, coordinate with property managers to identify open questions and activate key players (e.g. district heating companies) to utilize the potential for CO_2 emission reductions, as well as provide more open source data where available. We suggest that national bodies provide common standards for data formats, develop legislation that would dynamically follow the developments in data science, and support and develop initiatives for open data and co-creation.

Kommentar fra Københavns Kommune/ A comment from The City of Copenhagen

Det har været meget spændende at deltage i IDASC projektet, hvor nye AI (Artificial Intelligence, kunstig intelligens) værktøjer skulle stå sin prøve i Tingbjerg og selvom dette område er relativt småt, så kunne der findes målbare besparelser ved øget viden om lokale vejrforhold og regulering af fremløbstemperatur. Hvorfor er det så ikke bare "plug & play" for resten af forsyningsområdet? Det er der mange grunde til og et af dem er datatilgængelighed og sikkerhed. Målerdata er primært til brug for afregning af energi og temperatur i nettet hører til i driften, som skal sørge for at alle forbrugerne kan få den nødvendige varme. AI løsninger vil ofte gå på tværs af organisationen og dermed ansvarsområder, hvilket gør at det tager tid at implementere og få aftaler på plads vedr. GDPR regler mellem forsyningsselskab og leverandør af AI-løsning. Men netop denne type af samarbejder mellem forsyningsselskaber, universiteter og virksomheder, hvor vi samarbejder tæt og gennemfører pilottest vil bane vejen for brug af digitale løsninger. Det næste "bump på vejen" er rammebetingelserne og afgiftssystemet, idet de grønne afgifter bør revurderes for at initiere CO_2 besparelser og mulig sektorkobling.

(English translation) It has been very exciting to participate in the IDASC project, where new AI (Artificial Intelligence) tools were tested in Tingbjerg. Although this area is relatively small, measurable savings could be found by increasing knowledge of local weather conditions and regulating the flow temperature. So why not just “plug and play” the solution for the rest of the supply area? There are many reasons for this and one of them is data availability and security. Meter data is primarily used in settling energy bills, while the temperature in the grid belongs to the operation, which must ensure that all consumers can get the necessary heat. AI solutions will often go across the organization and thus areas of responsibility, which means that it takes time to implement and get agreements in place regarding GDPR rules between a utility company and AI solution provider. However, precisely this type of collaboration between utilities, universities and companies, where we work closely together and carry out pilot tests, will pave the way for the use of digital solutions. The next "bump in the road" are the framework conditions and the tax system, as the green taxes should be re-evaluated to initiate CO_2 savings and possible sector coupling.

Acknowledgements

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Contents

1 Introduction

1.1 Background

This report is a deliverable of the IDASC (Intelligent Data Anvendelse i Smart Cities - Intelligent data use in smart cities) project, funded by the Capital Region of Denmark. It has been prepared by DTU Management, The City of Copenhagen and DTU Compute. As part of the project, IDASC tested different models for using more real-time data in district heating systems, so that senior executives, decision-makers and politicians involved in the district heating sector can be acquainted with technical advantages and economic savings, as well as CO_2 reduction potential related to efficient and fair energy data economy. We hope that the report can serve as a 'guide' for stakeholders dealing with broadly understood data in the energy field in Denmark. We also hope that it can contribute to other strategic Danish initiatives, such as e.g. Digital Hub Denmark, Center Denmark (EU ERA-NET Smart Energy Systems Digital Platform Provider), Smart City Cybersecurity Lab, etc.

1.2 Problem formulation

Ubiquitous smart meters and sensors are revolutionizing our energy systems, providing a large amount of data. A cross-sectoral energy digitalization can contribute to reducing CO_2 emissions, improved flexibility and increased energy efficiency and competitiveness. In such a flexible energy system, electricity and heating systems are interconnected so that the heating network can act as a storage facility for renewable energy, and the buildings - as heat storage during the peak load period. However, collecting and using the increasing amount of energy-related data from buildings, supply companies and the grid is a challenge because the various data initiatives are uncoordinated, making it difficult to share data across stakeholders: municipalities, companies and national institutions. Moreover, the uncertainty about the benefits of various initiatives, security and privacy in data sharing efforts, as well as silo mentality due to traditional organization and legislation also hinder the potential for increased digitalization. We believe that municipalities need generic knowledge and good data governance for coordinating different stakeholders towards sustainable data sharing that benefits society. As aforementioned, the digitalization of energy systems can facilitate CO_2 and energy savings. Although precise quantification is difficult, it is possible to use case studies to estimate the impact digitalization can have on CO_2 emissions and energy efficiency. We hope that this report will be the first step towards increased understanding of efficient use of energy data across actors and of the value of energy data in relation to expected savings and value creation.

1.3 Objectives

This study is divided into three main tasks: energy data mapping, analysis of barriers, and assessment of gains data can provide with a focus on energy and CO_2 savings. The report concentrates on the following issues:

- What data are available in the energy field, at what frequency and who owns it?
- What challenges to data collection, storage and sharing are there, as perceived by selected actors within the Danish energy sector?
- What value can data and its analysis provide to different stakeholders in the energy field?

The geographical focus of this study is primarily the Greater Copenhagen area. However, national institutions, which influence the decision-making in Copenhagen, are also part of this analysis. Moreover, examples from other Danish locations are discussed to provide a larger evidence base.

1.4 Methods

Data in this report was collected using literature review of scientific articles, white papers and results from other research projects. Furthermore, empirical data was collected using 12 in-depth expert interviews with representatives across the district heating value chain in the Greater Copenhagen area between August 2020 and May 2021. The interviewed experts represent the following organisations (in the alphabetical order): Center Denmark, Copenhagen Properties, Danish Energy Agency, Energinet, ENFOR, HOFOR, The City of Aarhus, The City of Copenhagen, Varmelast, and an energy law specialist.

2 Overview of legal frameworks for data use and sharing

The existing legislative frameworks set the general rules for energy data use and sharing. Data protection rules are laid down in the EU Personal Data Regulation [1] and the Danish Data Protection Act [2]. Energy suppliers and grid companies need to collect and process personal information related to the individual customer (e.g. name, address, telephone number etc.) for use in the administration of their contractual relationship. Moreover, the supplier has to obtain the customer's consent for processing their CPR (personal identification) number [3]. The aforementioned Danish Data Protection Act provides more explanation on how processing of such ordinary personal data should take place.

The Directive on open data and the re-use of public sector information (Open Data Directive) [4] provides common rules for a European market for public sector information and aims at improving transparency and re-usability of data, e.g. by stimulating dynamic data publishing and developing policies for open access to publicly funded research data. It also anticipates further legislation listing so-called high-value datasets to be made freely available.

In order to allow even more data availability, the European strategy for data from 2020 [5] focuses on designing a market for data while ensuring respect for EU rules and values regarding data protection, intellectual property and trade secrets. A deliverable of this strategy is the proposal for a Regulation on European data governance (Data Governance Act) [6], presented in 2020. The proposal aims to strengthen the trust in data sharing and introduce new mechanisms for data sharing. Its main elements are: access to public data (subject to other rights), rules for data intermediaries, “data altruism” frameworks, and formation of an expert group for data innovation.

3 Mapping of energy-related data and key stakeholders

Smart meters and sensors are becoming ubiquitous in modern energy systems, thus the (possibility for) abundance of data is evident. In this chapter, we provide an overview and categorization of data types relating to energy, existing energy data platforms, as well as main Danish stakeholders who collect and utilize energy data.

3.1 Examples of energy data types, sources and characteristics

In general, energy data can be classified into non-sensitive and sensitive data "of different types, formats, meanings and sizes" [7]. Table 1 attempts to categorize the key data types available in the energy field in Denmark. Please note that due to the dynamic developments in data science and data provision, the presented data sources are just examples and more energy-related data may be available for interested users. Out of six categories displayed in Table 1, the four largest data sources are: energy supply data, registry data, local building data and weather and climate data. While not all the data is freely accessible for everybody, in recent years a significant progress has taken place, caused by implementing new data platforms such as e.g. Datahub. Please see section 3.3 for more information about large energy data platforms and ecosystems in Denmark.

Table 1. Non-exhaustive categorization of key energy-related data accessible in Denmark: types, availability and characteristics, own study based on Niras [8] and Rambøll [9].

Category	Data type	Data availability	Characteristics
Energy supply data	Electricity consumption (smart meters)	Energinet's Datahub [10] (see also section 3.3) and electricity sales companies	Real-time, delayed or historical, depending on the entity seeking access
	District heating consumption (smart meters)	Via respective DH supplier	Real-time, delayed or historical, depending on the entity seeking access
	Natural gas consumption (smart meters)	Via respective gas supplier	Real-time, delayed or historical, depending on the entity seeking access
Registry data	Data on buildings: Building and Housing Register (BBR) [11]	Building owners have access and are obliged to keep information updated	Registry data e.g. year of construction, ownership, type, use and area of building, heat installation
	Building and energy data - energy labelling reports	Access via Sparenergi.dk [12]	Energy label, building type, year of construction, supply type
Local building data	Own consumption data	Own smart meters	Real-time heating and electricity data
		Central control and management data (CTS)	E.g. inner energy consumption, lighting conditions, indoor climate, temperatures
	Municipal/regional key numbers; building data; usage data	Datasets for municipal buildings	Energy consumption per building; data on building operation; use of individual buildings
	Own key numbers	Own smart meters	Real-time heating and electricity data
	Experience-based knowledge	Local tacit know-how	"Standard" figures based on experience and dialogue
Weather and climate data	Weather conditions affecting RES production and energy demand	Free access from DMI's Open Access API[2] [13]	E.g. outdoor temperature, wind speed, solar irradiation etc.

[2] One of the DMI stations was used within the IDASC project to provide data for the case study in Tingbjerg.

	Local climate conditions	Own local climate stations (district heating companies[3], Varmelast)	E.g. outdoor temperature, wind speed, solar irradiation etc.
Key figures	Energy benchmarks from SBI - Green Accounts for Housing and for Schools	Access via AAU Build/SBI website [14]	Key figures for energy and water consumption and CO_2 emissions for households and schools
	Standard key figures from the Danish Energy Agency	Standard heat consumption for different building categories (kWh/m² p.a.) [15]	Standard data using historical values
Municipal energy accounts	Energy and CO_2 accounts	Access via Sparenergi.dk [16]	Overview of municipal CO_2 emissions and energy consumption in Denmark

3.2 Main stakeholders dealing with data in the energy field

The main actors nationally and locally in Greater Copenhagen that deal with energy data include private and public users, suppliers of data and suppliers of technology. Table 2 displays an overview of the main stakeholders that provide and use Danish energy-related data. In this report, we selected and interviewed some of them in order to understand the obstacles that hinder efficient energy data access, use and sharing (please see section 4 for details).

[3] Traditionally, the control schemes of the supply temperature at district heating suppliers were regulated as function of current outdoor temperature.

Table 2. Main stakeholders dealing with energy data in Greater Copenhagen and Denmark (in *italic* those analysed in more detail in this report).

Stakeholder type	**Example**	**Role in data provision**	**Data examples**
District heating supply company	*HOFOR*	Owner/responsible for data	Heat consumption from smart meters
Heat planning/scheduling entity	*Varmelast*	User	Energy production from CHPs in Greater Copenhagen
Electricity and gas Transmission System Operator (TSO)	*Energinet*	Owner/responsible for data	Electricity consumption from smart meters
National energy authority	*Danish Energy Agency*	Legislation and coordination User Data provider	National energy statistics, Building Hub (Danish: Bygningshub)
Providers of technology and services	*ENFOR*	User Data-driven service provider	Forecasts for energy systems operation
Municipalities	*The City of Copenhagen; The City of Aarhus*	User Facilitation and governance	CO_2 emission inventory, data on municipal buildings
Property management	*Copenhagen Properties and Purchases*	User Owner/responsible for own building data	Data on own buildings
Data platforms and provision systems	*Center Denmark*	Sharing and analysis	Heat, electricity, gas and water consumption for a number of households in Denmark
Weather data	DMI	Owner	Outdoor temperature, wind speed, solar irradiation etc.
National data collection and provision	Agency for Data Supply and Efficiency	Providing data infrastructure, analysis and standards; coordination	Building Hub (Danish: Bygningshub)

3.3 Examples of large energy data platforms and ecosystems

In this section, we describe four examples of data platforms and ecosystems in Denmark. They are in different phases of development and implementation, but we believe that there are some parallels among them. An increased collaboration across the different platforms could generate better synergy effects, helping advance energy system digitalization in Denmark even more.

3.3.1 DataHub and Energi Data Service portal

The Danish DataHub [17] is developed by Energinet and collects smart meter readings from 3.3 million registered consumption and production points, as well as information about change of address or supplier. An overall goal of the DataHub is to facilitate communication and business transactions (e.g. transfer of meter readings from the grid operator to the electricity supplier, who uses the information for billing) in the Danish electricity market. Furthermore, the data contained could be used to promote competition and improve market conditions for consumers. Electricity market participants get access to DataHub via their IT systems or the DataHub Market Portal. Consumers can access their own data via their electricity supplier or the webpage eloverblik.dk. Since April 2021, the structure for DataHub, called Green Energy Hub has been available open source on Github [18].

The Energi Data Service portal [19] gives access to several types of energy data for all actors, e.g. consumers, scientists, companies, concerning e.g. electricity consumption, CO_2 emissions, prices etc. The portal supports API, contains data guides and a dialogue forum.

3.3.2 Building Hub

The Danish Building Hub [20] is developed by the Danish Energy Agency (DEA) and Agency for Data Supply and Efficiency (ADSE), as part of the Danish Climate Agreement. A test facility for the Building Hub will be built in Aarhus, where DEA and ADSE will collaborate with Aarhus municipality, district heating company Aarhus Affaldvarme, and Energinet. The platform will provide data on buildings from BBR, energy label scheme, weather conditions from DMI's weather stations and hourly electricity and heat consumption data with a 1-day delay. The platform has an overall goal to facilitate energy efficiency and flexible energy consumption, by providing access for building owners, contractors, companies that develop energy saving services etc. First results of the platform are expected in autumn 2021 and the testing will end in 2022. Experiences with the test facility may lead to establishment of a nationwide Building Hub in the future.

3.3.3 Center Denmark

Center Denmark [21] is a non-profit, independent company that provides digital infrastructure facilitating energy data sharing and utilisation, and a business incubator called Digital Energy Hub. So far, accessible data includes 15-minute interval smart meter readings for electricity, heat and water from areas in Jutland, as well as heating and indoor climate data from selected Living Labs. Access to the data can be gained through paid subscription to the data platform.

The data platform is a bidirectional data lake, where a user can access their own closed protected environment where they can upload and access data. There is a spatial and temporal approach to data processing and viewing. The Flexible Energy Denmark Data Lake (FEDDL) (see also Hamadou et al. [22]) is deployed in the Center Denmark Cloud. The data in FEDDL are organized into directories divided into three zones, including Landing, Work and Gold zones. The Landing Zone is the staging area where raw data are loaded into FEDDL. This zone stores the data collected from living labs (LLs), without applying any data cleaning or processing. The Gold Zone contains the clean and well-structured data, which are quality ensured, e.g. all authorized FEDDL users may store aggregated results after applying advanced processing to the DSOlab energy data. The Work Zone stores intermediate data sets, which are processed, cleansed, or enriched with the data from the landing zone. Once the data have been processed, the cleaned data will be moved from the Work Zone to the Gold Zone. FEDDL users can access and explore the data in the Gold Zone. The technical architecture of FEDDL is composed of five layers, including Data Sources, Data Collection/Ingestion, Data Storage, Data Exploration, and Data Consumers, and four crosscutting layers, i.e., Access Management, Meta Data Governance, Privacy and Anonymization (GDPR) and Resources

Management [22]. The Data Sources and Data Consumers represent the systems external to FEDDL, i.e., running outside Center Denmark.

By following a number of rules, Center Denmark aims to comply with data privacy and GDPR concerns. Among the suggestions are: data storage of critical data located only in Denmark, using non-anonymised data only if a valid reason exists, avoiding pseudonymisation as the sole anonymization technique, not creating keys for de-anonymizing data [23]. Additionally, Center Denmark uses a number of anonymization techniques, e.g. suppression, aggregation, noise addition, etc. [23]

3.3.4 Opendata.dk

Open Data DK [24] is a collaboration initiative of Danish municipalities and regions who strive to make their data easily accessible on a common data portal. The data shared is non-personal and can be used free of charge by anyone. Examples of available data are: data on municipal infrastructure, air pollution or socio-economic characteristics. All municipal and regional members of Open Data DK can use the portal to publish their data sets. The portal relies on the Open Source software CKAN from the Open Knowledge Foundation.

4 Perceived barriers for efficient use of energy data

4.1 Overview

While smart meters and sensors enable more and more detailed energy data, a number of challenges for efficient data collection and sharing still exist. These barriers hinder the possibilities for developing new products, services and business models, where data could be applied. As a result, opportunities for increased system flexibility, sector coupling, implementation of renewables and energy saving measures could be missed.

Overall, our findings show that regulatory barriers occur for most analysed stakeholders. Not all obstacles were mentioned for all actors, but in many cases, several intertwined barriers exist, often extrapolated due to insufficient coordination across stakeholders.

Table 3 displays a summary of barriers identified through interviews with key stakeholders. The barriers mentioned most frequently by the interviewees were: technical, related to data access and legislative.

Table 3. Summary of barriers identified in this study, as perceived by interviewees (Please note: AK=Aarhus municipality, CDK=Center Denmark, CphProp=Copenhagen Properties and Purchases, ENS=Danish Energy Agency, KK=The City of Copenhagen), source: own research.

	Stakeholder									
Barrier category	AK	CDK	Ener-ginet	ENFOR	ENS	HOFOR	Cph Prop	KK	Law specia-list	Var-melast
Legislative		X	X		X	X			X	
Technical	X	X	X	X	X	X				X
Data security				X		X		X		
Data access and usability	X	X	X	X		X	X		X	
Coordination/communication						X		X	X	
Organization/structural		X	X			X		X	X	
Insufficient knowledge						X		X		X
Political		X								
Cross-cutting			X							X

4.2 Legislative

All the interviewees recognize the overall importance of data protection regulations, especially regarding energy consumption data, which carries a higher risk of being misused than registry data, e.g. high frequency data from residential houses might be used to identify inhabitants. However, the interpretation of existing legislation for smart meter data ownership, storage, use and sharing brings about several challenges. These challenges are due to legislation perceived as complicated and unclear, which often results in uncertainties and time-consuming processes around agreements on data processing.

According to the interviewee from Energinet and the law specialist, in case of innovative tools and approaches, it can sometimes be difficult to define the legal basis and the purpose of data collection, as per law requirements.

The interviewee from Energinet admits that it can be equally challenging for lawmakers to provide legislation, because they need to weigh-in benefits and risks related to data use and privacy rights. Moreover, what often is unclear is the stakeholders' authority for linking and utilizing the data: "We only know measuring points in some categories, we cannot correlate them with how many people live in the household, how many square meters they have etc." (Interviewee from Energinet).

Stakeholders aim to obey the law, but often end up with overcomplying with legislation, e.g. they withhold data, which could easily be anonymised, in order to be on the safe side. As pointed out by the law specialist, another reason for withholding data may be utilities' wishes to protect their own interest and avoid the risk of other actors freeriding, e.g. using the data collected to generate their own customer base. Similar caution in sharing production and GIS data is expressed by the utility HOFOR, who in their data sharing collaboration with external entities often require non-compete clauses.

Interviewees from HOFOR also mention the high data collection burden (especially for data collected at the dwelling level) due to legal requirements: getting information from individual housing units, such as asking the individual user for permission to use data and maintaining agreements (when e.g. a resident moves).

4.3 Technical

The technical barriers oscillate around insufficient data quality and resolution as well as concerns about managing large datasets, particularly data aggregation, processing, storage and exchange.

Interviewees from ENFOR, Danish Energy Agency (ENS) and HOFOR acknowledge that the quality and resolution of smart meter data from district heating varies. This situation calls for common standards, likely inspired by fixed standards for reporting electricity data. Common standards are expected for the upcoming test facility for the Building Hub (see also Section 3.3) and possibly in a nationwide Building Hub. HOFOR also underlines that utilities' billing systems need to be able to provide a lot of data with a good sampling rate, in order to make use of data collected by smart meters. It is the view of the authors of this study that the problem could also lie in the resolution of meter data, i.e. missing digits to be able to get reasonable hourly data.

HOFOR has previously encountered issues with data cleansing and data structure during updates. Moreover, district heating companies tend to use smart meters data for billing purposes only. In the case study of Tingbjerg (see also Section 5.6), HOFOR has experienced challenges with changing the purpose of smart meters. Using them as feedback to the controller revealed that HOFOR's current data formats, smart meter sampling intervals and methods for data collection were different from what was required for the project to run, so efforts had to be made to create a parallel structure.

For Energinet, data exchange between systems and interfaces is among the challenges and could become even more problematic if both electricity and heat data were to be integrated.

ENFOR has concrete examples of how data exchange between systems can be a barrier in many district heating companies. In order to use smart meter data for optimizing the operation of a district heating network, a link between operation (pumps, flow etc.) and customer data has to be established. Since both data types are collected elsewhere, connecting them takes time. A similar view is shared by HOFOR.

Lacking advanced data management and analysis practices may end up in lost opportunities for valuable analyses, as pinpointed by an interviewee from Varmelast: "We continuously get a lot of data all the time, but we only look at it and validate it when we read it in (...). It can delay many processes because we wait for data from some producers before we can start making heating plans. When we start, we find that we are missing data from another producer, because the amount of data is so large that we cannot look through all the csv files, because then we will never be finished so we do not do a continuous validation of data" (Varmelast).

4.4 Data security

Data security is a barrier mentioned mostly by those stakeholders that administer large datasets, where cloud solutions are used. For example, the software developer ENFOR has experienced customers (outside district heating) who had security concerns due to data storage in the cloud. The customers were anxious about the risk of compromising data confidentiality, especially if metadata (a detailed context for the data) followed the dataset. Reservations about cloud solutions are also echoed by the utility HOFOR who has experienced cloud providers overtaking ownership of data stored and instead providing access to the utility, in this way limiting HOFORs data ownership rights.

4.5 Data access and usability

The majority of interviewees point at difficulties in the access to specific types of energy data. Several of them also mention poor data usability, understood as a possibility to use data effectively, efficiently and to bring value.

While some actors provide access to electricity consumption data (Energinet) and both electricity and heat data from some district heating suppliers (Center Denmark), a wider access to gas data is missing, explained by Center Denmark with lack of collaboration projects with natural gas suppliers. As experienced by ENFOR, even if access to heat data is given, sometimes metadata (a detailed context for the data) is missing, which makes it more difficult to understand what data is stored - and how to use it.

Furthermore, in the past, municipalities such as the City of Copenhagen could continuously access detailed electricity data. Currently they encounter challenges in receiving access to electricity data as well as disaggregating data on the level of BBR data.

Data storage options are crucial for usability, according to the City of Aarhus. For example, the planned Building Hub could be even more useful if it was a "data container/lake" rather than "data hub". The difference would be that in a hub you choose single data to be shown, while in a data lake you can compare all datasets e.g. for AI application and historical analyses.

Moreover, according to HOFOR, ensuring that their ForsynOmeter tool brings value other than just visualisation through a data dashboard for customers is a crucial task. While some customers can conduct energy analyses themselves, most of them require support from HOFOR e.g. through consulting.

4.6 Coordination and communication

Energy digitalization is a complex process with many stakeholders, which often requires sufficient communication and coordination. Otherwise, barriers may occur, causing discouragement, delays and unnecessary multiple data collection, as mentioned by three interviewed stakeholders.

Internal coordination regarding time and task prioritization and labour division between district heating network planners and IT-responsible has been an issue at HOFOR. Moreover, coordination and communication with external stakeholders may turn out to be a challenge, according to HOFOR and The City of Copenhagen. These challenges occur not only when talking about the exchange of digital data between APIs, but also when people from different area of work and/or departments and companies interact: “It has proven to be more cumbersome and time-consuming to talk to real people, even though data is there” (HOFOR).

HOFOR also points out that some collaboration initiatives, e.g. the Energispring partnership, target several groups of people with different backgrounds (e.g. technicians/operators and decision-makers), which means that the project outcomes often have to be communicated differently to them.

4.7 Organisational/structural

Organisational barriers are linked to the type of the organization and its internal structure, which influence how resources are allocated.

It is Center Denmark's experience that the process of "opening up" in district heating companies requires changes both internally and externally. Similarly, the City of Copenhagen gives an example of district heating companies not being involved enough in using detailed consumption data on energy savings possibilities when set against the investments in new supply. Such a low engagement of companies in data utilisation towards energy savings and their lack of incentive may require improvements in their organizational setup.

Publicly owned organisations such as Energinet may be more open (or even required) to share data than private actors. Energinet gives an example of other, privately owned TSOs abroad who tend to be less interested in data sharing. A reason could be that private actors do not wish to bear the costs of a data platform for making data available, while publicly owned organisations are allowed to internalize the costs. Furthermore, the law specialist has seen examples of electricity and heat providers withholding information in the commercial market.

The legal activities linked to GDPR agreements consume significant amounts of time, as experienced by HOFOR. This challenge also underlines the importance of good resource allocation. Another challenge is the lack of sufficient internal human resources in IT departments to organize and tackle the data integration process smoothly. Such a situation leaves out the process to non-IT people who may not have technical knowledge of the IT equipment or security and do not have the user rights either. Such barriers may be less pronounced in a smaller company.

4.8 Insufficient knowledge and skills

The lack of knowledge about the data and the users of data is a barrier mentioned by three stakeholders. There would be an enormous potential for valuable insights about the district heating in Copenhagen if data was studied by a skilled analyst, according to Varmelast. HOFOR argues that one of the biggest challenges of having energy monitoring systems is the need to request advice from a dedicated specialist, hired either in-house or as a consultant, who has competencies to use the tool to its full potential.

IT product developers tend to make complex solutions, but consider their customers as a homogenous group and forget to invest in customer service, according to HOFOR. However, users of data and IT solutions would require more specific support regarding the challenges they have, since even practicalities may cause issues for implementing data solutions.

The interviewee from the City of Copenhagen argues that municipalities do not have all the competencies and time required to provide detailed analyses with energy data. However, collaborations with universities could be a solution to this issue.

4.9 Political

The political challenges are mentioned by Center Denmark. While some preparatory activities are in place, there is so far a lack of political agreements concerning releasing data. Another barrier is caused by different agendas and a lack of coordination about who should be responsible for a nationwide data access, which results in some actors being reluctant e.g. to allow Center Denmark to host their data.

4.10 Cross-cutting

We have identified two crosscutting barriers for data collection and analysis: purpose-making and competing solutions/insufficient marketing of the advantages of data-driven tools. For example, Energinet argues that sometimes the benefits of digitalization are hidden and the societal value is indefinable. This lack of clarity is challenging for decision-makers who would like to invest money and lawmakers who provide legal frameworks, because both groups need a purpose for their activities.

Many interviewed stakeholders have already had their well-functioning tools of choice for data analysis for years. For example, Varmelast was satisfied with their previous solution, so they wanted to compare the old and new data-driven tool on many parameters: "It took a long time (...), because we have been really happy with our old program and wanted to make sure the other system was better before we switched."

4.11 Discussion

Our findings show that the barriers that occur for most analysed stakeholders are: technical, related to data access and legislative. Similar results were obtained previously at the IDASC Masterclass in March 2020 [25]. A live poll concentrating on the main barrier to digitalization and ideas to improve the current situation was conducted with participants. Out of 52 poll participants, 20% selected data integration among systems, 16% uncertainty about GDPR rules concerning consumption data, 14% missing knowledge and competencies. The rest chose the interaction between production, transmission, distribution and end-user, organizational anchoring and managerial support, investment costs of a new technology, last-mover effect (waiting for technology to mature), existing meters hindering data transfer and access to new data sources. Among the ideas for progressing in digitalization of district heating, the poll participants mentioned:

- visions and long-term business considerations
- new energy taxes and tariffs
- greater knowledge-sharing of experiences and methods
- better networking and inclusion of women and youth to increase enthusiasm and new ideas
- better competition to prevent monopolies
- strategies to handle new (low-energy) buildings
- fixed norms for communication between users and supply
- partnerships which contribute to common development

These views are also in line with the recommendations of this report.

A number of other studies have evaluated the barriers for energy systems digitalization. A lack of automatic district heating data collection systems comparable to the one for electricity made available in the Datahub is a crucial challenge [26]. According to Liu et al. [7], the quality of available energy data varies: the challenges may include lack of consistency, completeness and accuracy. In 2017, Rambøll conducted a study on the access to energy data [9]. The main challenges depended on the data type, but ranged from lack of access to data, missing standards, to uncertain data quality. Although the situation has improved since, the concerns of insufficient data standards are still valid, which is also confirmed with a recent report from Tekniq Arbejdsgiverne [27], where four primary challenges are described: lack of standards for data formats, many different data platforms in use, impossibility to get real-time data and lack of clarity about data ownership. The study authored by Niras [8] concludes that supply data, self-produced data from municipalities and regions and register data have inadequate quality and accessibility. Other challenges are lack of knowledge about the value of data, lacking data-technical competencies and insufficient coordination of the transformation process towards data-driven operations in real estate departments in regions and municipalities.

5 Value of energy data, digitalization and ICT implementation

5.1 Introduction

The need to highlight the value of digitalization and data analysis for various stakeholders echoes through many recent studies about energy data. Nonetheless, putting value on digitalization in the energy sector is very challenging regardless of whether it is measured in energy savings, CO_2 emissions reduction or financial savings. This is because an actual reduction or gain has to be compared after the implementation of a solution with a baseline established earlier - before the implementation. Since the process of determining the baseline before introducing a new digital solution is rarely done, a calculation of an actually achieved gain or reduction is often based on relatively generic or average data.

Currently, Denmark is being digitalized at a very high rate. The IDASC project has been carried out in the COVID-19 pandemic, demonstrating the high level of digital advancement in Denmark compared to other European countries. The pandemic did not have any specific impact on the Danish energy sector (neither supply nor demand) except for the transportation sector where the private car traffic was significantly reduced due to employees working from home instead of at the office. Indirectly, this situation could indicate the value of digitalization through the impact on society, the heat sector, education sector, and service sector in general. Digital solutions were quickly installed at a speed that had been unthinkable before the pandemic - not from a value proposition, but from an urgent need. A more concrete example could be homeowners installing indoor climate sensors due to raising concerns about air quality etc. caused by staying at home for longer periods.

Despite Denmark possibly being one of the most digitalised countries in the world, the digitalization of the energy sector as a whole is lagging behind other sectors in the economy. Some of the reasons behind that are discussed in Section 4. Nonetheless, energy digitalization is already providing numerous benefits to energy systems and their users. Below we discuss selected examples for monetary, CO_2 and energy savings resulting from an increased use of energy data. Table 4 depicts an overview of potentials for savings, depending on the location within the district heating value chain. Section 5.6 briefly discusses the case study of Tingbjerg (Copenhagen), which is part of the IDASC project.

Table 4. Non-exhaustive overview of data sources, challenges and possibilities for savings within the district heating value chain (source: own study).

Value chain location	Data sources	Data challenges	Data analysis potential for achieving savings
DH plant operation	-Forward and return temperature control at the DH plant and at the heat exchangers in the network -Temperature control at end user heat exchanger - in and out. -Monitoring the flow at production - also as part of temperature control with the aim to keep the supply temperature low while regulating the flow to meet the heating demand -Monitoring the pressure in the network -Determination of heat loss in the network. -Monitoring of outdoor temperature (local climate stations at DH production, regulating the supply temperature as a function of outdoor temperature).	-All operational data (e.g. temperature) owned by the plant owner. If the plant owner does not own the network, limited influence on out and in water temperature. -If the plant owner wants to discourage/encourage certain consumption patterns it can be done on return temperature to the plant. -Depending on the in and out temperature, possible to install a heat pump to reduce the return temperature - in which case getting a low return temperature is not required - an advantage if the plant has its own heat storage.	-The heat plant wants as low a return temperature as possible because it increases efficiency at the plant. The value of low temperature is relative. -Possible digital solutions (incl. machine learning) focusing on demand forecasting, using outdoor air temperature data, historic production/demand data, detailed temperature data from the network and at the end-user
Heat storage	-Temperature control of water flow in and out of heat storage.	-Heat storage either owned by the DH plant or network operator. Owner has access to temperature control data.	-Tools reducing heat losses in the storage.
DH distribution network	-Temperature control of dispatch and return water from and to the DH plant. -Temperature control of in and out water flow at heat exchangers in the network. -Determination of heat loss in the network. Temperature control at end user heat exchanger - in and out.	-Frequency of data logging -Approaches for data collection -If DH plant and network operator have the same owner, both will have access to the network temperature data. If not, they may not have access to each other's temperature data.	-The operator wants as low heat loss as possible. -Lower forward temperature reduces heat loss. -The operator wants to reduce leakage on network pipes as much as possible. -Possible digital solutions: using data on pressure,

	-Monitoring outdoor air temperature	-Unusual heat loss means there is a leakage somewhere in the network.	soil moisture and soil temperature, data on unusual heat consumption.
End-user	-Temperature control of water flow in and out at the end-user heat exchanger.	-Frequency of data logging -Approaches for data collection -The DH company and/or network operator will have to have access to the temperature data to be able to invoice the end-user. -If the supplier wants to discourage/encourage certain consumption patterns, then the supplier will need to collect regular data - e.g. hourly temperature measurements.	-Data to show in and out flow water temperature. -(Automatic) digital solution which can optimise heat consumption and reduce return temperature.

5.2 Energy and CO_2 savings

A possibility for achieving energy and CO_2 savings is a crucial driver for implementing digital solutions. The increased sector coupling between heating, cooling and electricity is blurring the difference between electricity and heat savings. For instance, the use of large and/or small heat pumps may reduce heat production at the district heating company but is dependent on the input of electricity. New efficient buildings may also increase electricity consumption due to a cooling demand during summer, unless the heat recovered from the cooling process is used for heating purposes somewhere else, e.g. domestic hot water. The optimal control and operation of these new buildings require very sophisticated digital control systems. The heating demand in these new buildings is very low and unless the access to district heating is readily available, it may not be cost effective to connect them to the district heating network. On the other hand, new solutions can be developed where these buildings operate as prosumers - producing heat and returning it to the district heating network. Moreover, as illustrated in the example of heating the water in swimming pools [28], it is possible to reduce CO_2 emissions by 5% at the same time as we increase energy consumption by 5%. In this section, we provide examples of savings in different contexts, as a first step towards a quantification of energy and CO_2-related benefits of digitalization.

In relation to district heating, advanced data analysis for improved network operation is an option for significant savings. For example, Damvad Analytics [29] has evaluated the potential for data-driven temperature optimization in the district heating system. A qualitative comparison was made with the known methods for simulation-based temperature optimization. The savings potential was mapped both at company and socio economic terms. The project clarified that data-driven temperature control has the potential to reduce the flow temperature by an average of 3-10 degrees. In addition, data-driven temperature optimization provides additional benefits, such as better options for integration of heat pumps in the district heating network and an additional saving potential of zone-divided data-driven regulation of temperature and pressure level [29]. A more comprehensive approach could be to apply crosscutting optimization platforms, such as one developed within the HEATman/Heat 4.0 project. It is expected to provide efficiency gains of up to 4%, due to lower heat price and environmental burden, as well as higher security of supply [30].

Small district heating networks can also reap benefits of digitalization. Customer-owned Svebølle-Viskinge district heating is located in Western Zealand and has 535 customers. The district heating company has a wood chip-fired heating plant, which supplies the vast majority of the heat to Svebølle and Viskinge. They also have a solar thermal site, which accounts for 20% of the annual heat consumption. The district heating company has initiated efforts on energy savings: the installation of smart meters, sensors, dashboards and temperature optimization tools has allowed for grid loss reduction of 8%. The forward water temperature in the network has been reduced almost by 13°C (from 80.9 to 68.1 °C), corresponding to about 450 MWh. The return temperature is now held under 40°C [31].

The Danish Energy Agency's initiative "Energy Efficient and Intelligent Buildings" gives examples of savings from digitalization and ICT [32]. For example, the digitalization of building operations can provide an annual energy saving of 2% of final energy consumption for space heating, lighting, comfort ventilation and comfort cooling (1,200 GWh in 2030) - but up to 11% if increased technology development is assumed [33]. Most companies can achieve energy consumption reduction by 15-30% by introducing energy management [34].

In Copenhagen, more than 700 million DKK has been used to reduce energy consumption in municipal properties: renovations, central monitoring systems (the consumption of electricity, water and heat in the municipality's buildings and facilities), planning energy saving efforts (e.g. heat is automatically turned down during holidays). As a result, the total energy consumption from the municipality's buildings has been reduced by almost 20 % since 2012 [35].

ForsynOmeter, a tool developed by the DH company HOFOR, helps customers to improve their energy management. The tool allows for collection and visualisation of energy consumption data, optimization of energy use, as well as provides automated energy monitoring and alarm systems. HOFOR argues ForsynOmeteR can save 10% on the bill by optimizing energy consumption [36].

The municipalities of Aarhus and Viborg have collaborated to test new methods for data-driven energy management, saving up to 8% on the energy bill in buildings in both municipalities. Five pilot buildings were equipped with smart meters and loggers, providing data for more targeted efforts to reduce energy consumption. As a result, standardized methods for analysis and benchmarking of buildings, behavioural interventions and visualisation of energy consumption were developed [37]. In another case, a simple wireless sensor acting as a link between different technologies installed in new buildings was able to save up to 25% energy [37].

5.3 Monetary savings

Putting a monetary value on savings achieved with digitalization is a challenging task, because it is very context-dependent. In this section, we describe some examples. Although the values provided cannot be directly transferred to other cases, they could serve as inspiration to conduct a detailed cost-benefit analysis.

The earlier mentioned report by Damvad Analytics [29] quantified the savings potential for data-driven temperature optimization to DKK 240 - 790 mio annually in the district heating sector.

Focusing on buildings, installing smart LED lighting in public buildings in the City of Copenhagen (97,000 m^2, primarily schools, day care centres and housing for the elderly) resulted in an annual saving of DKK 3.4 million [38]. The analysis and automated monitoring of ventilation systems in Roskilde Municipality's buildings gives savings of DKK 500,000 [37]. In Aarhus and Viborg, savings on the energy bill as a result of the project on data-driven energy management were DKK 951,989 annually [37].

5.4 Possibilities for new services, products and business models

The digitalization of buildings and district heating networks brings about possibilities for new services, products and business models. While an exhaustive list of such possibilities is beyond the scope of this report, stimulating innovation is among the largest benefits of energy system digitalization, albeit difficult to quantify. Accessible energy and weather data and advanced tools for analysing it have resulted e.g. in university spinoffs developing new optimization and energy tracking tools and innovation sprints organized e.g. by the Danish TSO Energinet. These resulted in a development of new services such as a possibility for large commercial buildings to deliver flexible electricity consumption as services to Energinet [39]. These services could provide up to 100 MW in consumption flexibility in a longer term, allowing building customers to make money or reduce the cost of refrigeration and ventilation systems.

Our interviews have also shown that stakeholders in the energy area in Denmark are vividly interested in data collection and analysis and are eager to collaborate to obtain more knowledge about buildings (e.g. efficient property utilisation, energy renovation potentials, occupant behaviour, EV charging patterns), networks (e.g. reduction of forward and return district heating temperature, peak shaving, local weather data as a control instead of sensors that measure the temperature) and overall energy system (e.g. long-term modelling analyses, sector-coupling potentials).

5.5 Job creation and export potentials

An increased digitalization may also lead to larger potentials for job creation and technology export. Although no data specifically on the influence of digitalization was found, an indication is given by following the recent developments overall in the district heating sector. For example, the employment in Danish district heating industry has increased by 30% from 2012 to 2017 [40]. In 2017, the industry had a total of 22,500 full-time jobs associated with the district heating sector, either directly in the district heating sector or derivative jobs. 10,786 jobs were created directly in the district heating sector, out of which the district heating industry accounted for 7,990 jobs. Consulting engineers accounted for 990 jobs and the heat supply for 1,806 jobs. The number of jobs for subcontractors, i.e. the derivative jobs, 11,715 were created because of the district heating sector's acquisitions of goods and services. Although the industry's turnover has fallen in 2018, the overall development has been an increase of 11%. The industry exported for a total of DKK 6.41 billion DKK in 2017 [40].

5.6 IDASC demo case: Tingbjerg in Copenhagen

This section primarily concentrates on savings in Tingbjerg - for more details about the area and the solutions provided, please consult the separate technical IDASC report "Experience of using Data-Driven Methods in District Heating: Digitalized Operation in Tingbjerg, Copenhagen" by Bergsteinsson et al.

The IDASC demo case in Tingbjerg is a proof of concept for data-driven district heating temperature optimization and its value. Tingbjerg is an area consisting of 43 large building customers, located in HOFOR's area, but isolated from the rest of Copenhagen's network and supplied with its own heat exchanger. Most of the customers have smart meters with a resolution of one hour. The temporal resolution has since improved to every 15 minutes, sent once an hour. The supply temperature is around 68 °C in summertime and 85 °C in the heating season.

The demo case consisted of three interventions: installing and running ENFOR's software tool HeatTO [41] for supply temperature optimization and control, using the smart meters as feedback to the controller and using local weather climate stations instead of scaling the heat load forecast from a larger area. The overall aim was to lower the supply temperature and give better control of the network in Tingbjerg, as well as providing savings for the utility thanks to lowering the supply temperature and decreasing the heat loss in the network.

As discussed further in the two other deliverables of the IDASC project, due to time limitation in the trial period it was impossible to optimize on control curves and thus the feedback, so the savings potential of the data-driven automatic feedback is unfortunately unknown in Tingbjerg. However, HOFOR now uses the data-driven method in Tingbjerg, and there are quite good experiences. Furthermore, the results after the interventions demonstrate a more robust supply temperature than without the controller. There are fewer large temperature fluctuations over a short time period compared to the previous operation. Although a lower supply temperature had been expected, the DH operator's restrictions on the supply temperature were set slightly higher than without the new controller. If a more suitable reference curve had been used, the supply temperature could have been lowered as compared to previous operation and the temperature would have been even more robust - with expected savings in network maintenance costs to follow in the longer term.

5.7 Discussion

Digital solutions, digital gadgets, digital data flows have had a big impact on our daily life during the last two decades. Two decades ago, we would not have been able to do many things we do and take for granted today. The digital world and access to data makes us able to deal with routine tasks and complex strategies just with a click on the phone, tablet or computer. The access is quick and efficient because we are no longer willing to wait too long. It is driven by the desire for comfort - many services are even free - but nothing is “really free”. Data has been phrased as the new “gold” and the service provider obviously needs to have an in-direct way of making a profit. This is then typically achieved with sophisticated data analytics, where the service provider is able to pull out information in the data use - and sell it to someone who is willing to pay for that information.

The digital world is also available for the energy sector, where the opportunities are abundant, right from the energy production site, distribution and to the end-use energy demand. The change towards intermittent renewable energy makes energy production dependent on the weather, which is unpredictable. Nevertheless, with good weather forecasts it is possible to make the utilisation of renewables more predictable. Especially heating demand is very dependent on the weather (air temperature, wind speed, solar influx). 24-hour weather forecasts are important in both the power and the heating sector. Shorter time spans make weather forecasts even more reliable - forecasts in hours, minutes and seconds into the future are crucial for the power sector, but less important for the heat sector.

The technical requirements for supply are not as critical for heating as for power supply. This is another reason to exploit digital solutions that combine the detailed understanding of the variable renewable energy sources (VRES) and the heat demand. However, the heat supply via the district heating network has a slow response time as the heat may take 6-12 hours to be transferred from the heat source to the heat sink. The heat loss may be e.g. 10-20-30%, so it is obvious that a good understanding (accurate data and its analysis) of the piping network, temperatures and flows is needed to reduce heat loss as much as possible. This can be achieved with relevant hardware, software and other digital solutions and services.

Many heating networks are old and established at a time when there was less focus on energy efficiency and use of VREs. The old networks were established based on a heat production plant to deliver heat to the consumer with little consideration of energy efficiency and heat loss in the network with a regulation, which forced the consumer to connect to the network. There was then little incentive to develop the most efficient systems. This situation has completely changed so district heating companies are faced with both a desire to achieve carbon neutrality and at the same competition from alternative heating technologies, which are not connected to the network.

An expansion of existing DH systems and establishing new networks is severely challenged under the new regulation. That is a pity because these expansions or net networks could then be implemented with new and more efficient technologies. However, due to the lack of incentives to connect to a network the business case is very challenging for a district heating company.

Technically, any district heating system could be fossil fuel free, but a transition to a fossil fuel free system may be expensive and also depends on detailed regulation, which would not allow a change to fossil fuel free system even though it is financially doable. A drive towards carbon neutrality is boosting VRES. The optimal use of VREs requires fast control and response, which can be accomplished with digital solutions. Moreover, savings obtained thanks to these solutions allow DH to remain cost competitive in comparison to e.g. individual heat pumps.

6 Conclusions and recommendations

6.1 Conclusions

The growing level of digitalization in the energy system and the abundance of energy data from smart meters and sensors is becoming a reality. However, the barriers for efficient energy use across stakeholders and the value data can bring are not fully understood yet. In this report, we have shed a light on those aspects and provided a number for recommendations towards enhanced energy data use in Greater Copenhagen and Denmark.

The main stakeholders nationally and locally in Greater Copenhagen that deal with energy data include private and public users and suppliers of data, as well as suppliers of technology. Our mapping and categorization of data relating to energy show that the four largest data sources are: energy supply data, registry data, local building data and weather and climate data. While not all the data is freely accessible for everybody, recently a significant progress has taken place due to new data platforms and ecosystems in Denmark. An increased collaboration across the different platforms could generate better synergy effects, helping advance energy system digitalization in Denmark even more.

However, collecting and using the increasing amount of energy-related data from buildings, supply companies and the grid is a challenge because various data initiatives are uncoordinated, making it difficult to share data across stakeholders such as municipalities and companies. This study shows that key actors believe that legislative, technical and data access-related barriers still exist for efficient data collection and sharing. Other frequently mentioned barriers are organizational, insufficient knowledge, insufficient data security, and insufficient communication. In many cases, several intertwined challenges exist. These barriers hinder the possibilities for applying data in analyses that could reveal potentials for increased system flexibility, sector coupling, CO_2 emission reductions, implementation of renewables and energy saving measures.

The need to highlight the value of digitalization and data analysis for various stakeholders echoes through many recent studies about energy data. In this report, we have made several findings about the value of energy data. Efficient data use can result in improved system flexibility, energy, CO_2 and monetary savings and a development of new business models, job creation etc. A cross-sectoral energy digitalization can contribute to reducing CO_2 emissions, improved flexibility and increased energy efficiency and competitiveness.

Nonetheless, putting an exact value on digitalization in the energy sector is very challenging regardless of whether measured in energy savings, CO_2 emissions reduction or financial savings. This is because an actual reduction or gain has to be compared after the implementation with a baseline established earlier - before the implementation. Since the process of determining the baseline before introducing a new digital solution is rarely done, a calculation of an actually achieved gain or reduction is often based on relatively generic or average data. To sum up, although a precise quantification is difficult, we have provided a number of examples to estimate the ranges of impact digitalization can have on energy systems.

6.2 Recommendations

Based on our analysis, we provide a number of recommendations, divided into three target groups: companies, municipalities and national bodies (including national institutions and nationwide organisations).

6.2.1 Companies

Companies involved in energy data collection and sharing include e.g. district heating companies, software providers and electricity distribution and sales companies.

To tackle the time-consuming and overcomplicated data protection negotiations, templates for data agreements and guidelines for legislative processes could be implemented. Furthermore, experience sharing concerning data handling is crucial, e.g. developing different data techniques for data preprocessing, e.g. relevant data aggregation, electricity data anonymization in relation to the network topology etc.

6.2.2 Municipalities

Municipalities have a triple role in the digitalization process: data analysis, often in collaboration with their own building-responsible employees, facilitation, and data governance.

It is important that municipalities get involved in better data utilization, especially in long-term challenges. Data could be better used on the municipal level - and advanced data analysis is much easier if data is owned - such as in the case of municipal properties. For example, by coordinating with property coordinators to identify open questions, activating key players, and assessing possibilities for energy efficiency on the city level, such as energy renovation and avoiding excessive capacity increases on the side of district heating companies. Data access should also be improved by providing more data (e.g. anonymized energy consumption for all properties in a municipality) and making information on data portals such as opendata.dk (see also section 3.3.4) available in English. In relation to external actors, municipalities could increase collaboration with natural gas suppliers to provide gas data.

The decision-making processes concerning data governance and facilitation of digitalization initiatives on the municipal level also need to be improved to address the barriers identified. Experiences from Aarhus show that for data governance, collaboration on a strategic level and conducting many smaller projects are crucial for a smooth digitalization. The strategic anchoring of collaborations can tackle the structural changes in either collaborating party. This shows the relevance of initiatives like Building Hub and Center Denmark, because they give the involved participants more reasons to share their data.

6.2.3 National bodies

Common standards for data format or frequency should be promoted and we believe this activity is best to be centralised e.g. within the Danish District Heating Association or Center Denmark.

Moreover, the regulation around digital technologies poses new challenges to legislators. The juridical hesitations can be avoided if thorough analysis is conducted for developing methodologies for anonymizing and aggregating data at the right level. We also recommend better future proofing of the legislation, understood as the need to dynamically follow the developments in data science, and provide a challenging balance of easily understandable laws that are not too rigid at the same time.

The national bodies should support independent initiatives like Center Denmark and further develop the Building Hub, because they give incentives to collect data on a larger scale and to push common standards. Our recommendation is that the two initiatives collaborate more closely to avoid a parallel development. Furthermore, a political decision regarding a national Building Hub will ease the prospects for nationwide data collection and sharing efforts.

Moreover, activities similar to Energinet's Open Door Lab, which stimulate co-creation with external actors, should also be made widely available. While several initiatives for open data are in place already, e.g., Energinet has published the code for their “Green Energy Hub”, open data ideals should be embraced by other national bodies and actors who are willing to share data. This often occurs in connection with research and development projects.

More information should be shared with consumers, e.g., easily understandable guidelines about how to access one’s own energy consumption data. Making energy data available is also a way to deal with inquiries electricity and district heating companies receive from various actors who would like access to their data. The inquiring parties could instead contact a designated data provider, which would make it easier for them because the provider has the infrastructure ready and data in the quality and the anonymization level as required.

We hope that this report has been a valuable reading for stakeholders dealing with broadly understood data in the energy field in Copenhagen and contribute to other strategic Danish energy data initiatives. The dynamic field of energy data analysis requires a close follow-up in the years to come in order to understand all the potentials of digitalization and energy data utilization towards the green transition.

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Appendix A Interview protocol

Background
-What is your role in this organization? (Title? Employment seniority? Background / experience?)

The "data journey" in the value chain
-What access to which data type have you had and do you have now?
-How is your energy data organized, what data format do you use, etc.?
-How do you analyse data - what tools, typical analyses? What data analysis algorithms do you use, if any?
- Do you experience any barriers to efficient data use? If so, which ones?
    Are there any legal challenges for data sharing, if any? (e.g. data security, purpose, consent)
    Financial?
    Technical?
    If other, which ones?
-If data provider: How to avoid double data collection and how can data be used by stakeholders?
-Would you like more data to be available, in another form / frequency? Why / why not?
-What further plans for digitalization do you have?
-How do you integrate / coordinate data and what is the purpose?
-Are there common standards for data formats that determine what information should be included in data deliveries?

Data sharing
-Who do you collaborate with on data sharing and how?
-Can open data support (new or improved) applications for your data? If yes, in what way? If no, why?
- Where do you see weaknesses regarding data availability and what opportunities for improvement do you see?

Business models and value in data
-What value do you think energy data has for your organisation and in general (E.g. increased savings in energy consumption and CO_2 emissions, etc.). Do you have any figures on the savings?