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# Developing security of supply in the Swedish district heating sector – methods, challenges, and needs

Emelie Lantz

*AFRY, Sweden. E-mail: emelie.lantz@afry.com*

Tove Raquette

*AFRY, Sweden. E-mail: tove.raquette@afry.com*

Henrik Hassel

*Division of risk management and societal safety, Lund University, Sweden. E-mail: henrik.hassel@risk.lth.se*

Kerstin Sernhed

*Department of Energy Sciences, Lund University, Sweden. E-mail: kerstin.sernhed@energy.lth.se*

Peter Dannbring

*DHC Advisory AB, Sweden. E-mail: peter.dannbring@dhc-advisory.se*

Energy supply is a critical societal function, where disruptions can quickly lead to serious consequences for populations, industries, and other societal functions. Ensuring resilience therefore requires not only the ability to withstand interruptions, but also the capacity to adapt and recover from crises. In Sweden, district heating plays a particularly important role, supplying heat to more than half of all heated buildings in urban areas. Against the backdrop of a rapidly deteriorating geopolitical situation in Europe, there is an urgent need to strengthen security of supply, particularly in relation to the increasing risk of armed conflict, including hybrid threats. However, developing security of supply in district heating presents several challenges. Many measures are costly, especially if addressed individually by local actors, and district heating operates in a competitive market where prices are already close to the limits of customer acceptance. At the same time, district heating has been a cornerstone of Sweden's green transition, while alternative heating solutions, such as heat pumps or electric heating, may prove less resilient under future disturbance scenarios that Sweden needs to consider. This paper presents an interview study with Swedish district heating actors, aiming to examine how security of supply is addressed in practice. The study explores the methods currently used, the challenges encountered, and the needs perceived in order to further strengthen security of supply. The results show that security of supply is developed through a range of approaches, including technical measures, organisational practices, and forums for collaboration. Together, these findings provide a basis for improving conditions for local district heating actors to enhance resilience to a broad range of threats while simultaneously pursuing other strategic objectives, such as profitability and sustainability.

*Keywords*: District heating, security of supply, resilience, practical challenges, civil defence.

## 1. Introduction

Security of supply in energy systems is the ability to maintain the energy system's functionality during disruptions that occur in everyday operations, as well as during crises, periods of heightened alert, and even war. It concerns not only the resistance to interruptions but also the capacity to adapt and recover from sudden changes in the environment (Hotchkiss & Dane, 2019). The area has gained increased attention recent years, in particular after Russia's full-scale invasion of Ukraine and is therefore a key part in a nation's civil defence strategies. Disturbances in energy supply may quickly lead to severe consequences for populations and the economy (WHO, 2025, REACH, 2025, Łoskot-Strachota et al., 2025).

One critical type of energy infrastructure is district heating, which plays a key role in many countries as a main source of heating. District heating systems distribute heat from one or several centralised generation facilities through networks of pipes, using a variety of energy sources including biomass, waste, industrial excess heat, heat pumps, and in some cases also fossil fuels. In Sweden, which is the main focus of this paper, district heating plays a particular key role, supplying heat to more than half of all buildings in urban areas and 90% to block of flats. (Energiföretagen, 2025). Furthermore, in Europe there are plans to expand district heating to replace gas as a heat source.

The fundamental design of district heating offers major advantages in terms of efficiency, robustness to everyday disturbances and utilisation of local resources. Additionally, district heating can be a key enabler of a country's sustainability and green transitioning strategy as renewables can be the major energy source (Euroheat & Power (2025), 2025). This is the case in Sweden where non-fossil energy currently constitutes 71% of the total energy use.

The centralised and network-based nature of district heating systems can create systemic dependencies, for example on generation facilities, pipeline infrastructure, and fuel supply chains (IEA, 2023). Trends such as digitalisation and globalised supply chains add further to complexities and vulnerabilities. Disruptions, in particular during cold periods, may quickly lead to large consequences and with the growing threat of armed conflict, district heating system may be a target for attacks; something that is seen daily in Ukraine due to the Russian attacks.

Historically, resilience within the Swedish district heating sector has often been addressed as part of system design, operational and maintenance practices. However, increasing security concerns and the growing recognition of district heating as potentially security-sensitive infrastructure highlight the need for more systematic and structured approaches to risk identification and protection (Energi-myndigheten, 2023).

Despite the sector's importance, there is limited knowledge about how district heating organisations address security of supply. Priorities of authorities and international organisations (IEA, 2025) as well as earlier energy security research has primarily focused on electric power systems, gas and oil supply (Winzer, 2012; Cherp & Jewell, 2014), leaving local district heating systems underexplored. Ensuring the long-term resilience of energy systems requires knowledge of governance structures, institutional conditions and how energy systems are operated and managed in practice (Goldthau & Sovacool, 2012).

Given this background, there is a clear need for a more detailed understanding of current practices related to security of supply in the Swedish district heating sector. This includes how district heating companies work to design and improve security of supply, which processes do they adopt, which methods do they use, what factors affect this work, what challenges and constraints do they face and what needs do they perceive to be able to further develop their resilience.

This paper is part of a broader project whose aim is to develop and/or improve methods to define and operationalise appropriate levels of security of supply, i.e. to decide on plausible performance levels and implement measure as to achieve these levels of performance. By systematically identifying and structuring experiences, methods, needs and challenges, this study aims to create a knowledge base that can support subsequent method development.

## 2. Method

This study adopted an exploratory and inductive design, with semi-structured interviews as the primary method of data collection. In total, 14 interviews were conducted with 20 participants, each lasting between 40 and 70 minutes and involving between one and four participants per interview (with the majority conducted as individual interviews). The interviews were conducted online and transcribed verbatim. Before the interviews, a letter of consent was sent to the respondents, explaining the purpose of the interviews, how data would be handled, and that participants could withdraw from the study or choose not to answer any questions at any time. Since sensitive information could potentially be shared during the interviews, it was emphasised that the purpose was not to elicit technical details or specific risks, but rather to explore overall trends and recurring patterns related to methods,

ongoing work, and challenges experienced by professionals.

The analysis followed an inductive qualitative manifest content analysis inspired by Graneheim and Lundman (2004), focusing on the explicit content of the interviews rather than underlying meanings. More specifically, the transcribed material was read repeatedly to develop a comprehensive overall understanding. Units of meaning, relevant to the study's aim were identified, condensed, and coded using short descriptive labels. Then, codes with similar content or context were sorted into categories describing the manifested content which answers questions such as what, who, or where. To reduce the risk of researcher bias, the coding and thematic structuring were discussed iteratively among the authors.

In the next step, categories were compared and grouped based on similarities in content to summarise recurring and explicitly expressed patterns in the interview material. The result was eight themes, which were used as an organising structure for the presentation of the results.

## 3. Results

Based on the analysis, recurring and explicitly expressed patterns were identified and organised into themes to structure the presentation of the results in this paper.

### 3.1. *Technical arrangements for maintaining security of supply*

A key aspect of the security of supply for district heating lies in the technical disposition of the systems. Here, respondents describe redundancy in both the generation facilities and network as crucial.

In the generation, district heating companies aim to build capacity at multiple locations and to keep the system operational even if individual generation units are disrupted. This capability serves both to avoid large-scale negative consequences (a preparedness strategy) and to ensure an attractive heating service for customers (a business strategy). Respondents further argue that a complement to generation unit redundancy is to have access to mobile, small scale, temporary generation units that can be connected at certain access points (e.g. where sensitive customers are) in the network.

When it comes to the network, respondents mention redundancies where multiple paths between heat sources and customers gives possibilities to circulate the water in several ways if there are pipe breaks. This relies on planned network sectioning so that leaks can be isolated and heat secured for the most critical customers during crises.

Since district heating systems are geographically spread out, there are also many points where hazards and threats may expose the system. Respondents acknowledge that the increasing threat of military invasion, and with experiences from Ukraine where energy infrastructures are often targeted, there is a growing recognition of physical vulnerabilities. This is coupled with a realisation that it is difficult or very expensive to completely fortify the system against large-scale attacks. Instead, some respondents argue that only particularly critical parts can be protected and then capabilities to quickly rebuild and recover is most likely the more effective and efficient action.

### 3.2. *Managing fuel supply under uncertainty*

Fuel supply is claimed to be a critical part of both business (cost-effectiveness) and preparedness (robust and resilient) strategies of district heating companies. Here, increasing the diversification of fuels, e.g. by making sure boilers can operate on multiple types of fuels, is a key strategy to deal with both fuel price fluctuations and the risk of disruptions in deliveries of some fuels.

Interviews indicate that parts of the district heating fuel supply are perceived as dependent on stable cross-border flows, particularly for certain fuel fractions, which may be regarded as vulnerable during periods of war-related conflict in Europe. At the same time, although the Swedish forestry sector is extensive, interviews suggest that the current system for supplying forest-based fuels – including logistics, storage, and handling – is not designed for a rapid large-scale expansion of fuel supply to the national district heating sector in times of crisis.

In some sense, resilience was historically higher due to the use of oil which can be stored for a long time at large quantities. However, with the green transition, oil has long time ago been mostly phased out in the heating sector in Sweden; and having equivalent quantities of biomass locally stored is challenging both due to

both the properties of the fuel and the storage space required.

The interviews show that industrial waste heat is increasingly being used as a cost-efficient and sustainable source of energy. However, as a source of energy during periods of extreme disturbances, such as wartimes it is seen as less reliable.

### 3.3. *Dependence on external infrastructures and actors*

The district heating system has a lot of external dependencies, which means resilience in district heating is not entirely up to the district heating actors themselves. Electric power supply, water supply and input materials, such as various chemicals, are among the most critical dependencies of the district heating system. Spare parts are another critical dependency. Power is needed for both generation and distribution, and even though the district heating system may be functional, the customers also need electric power to circulate the heat in the buildings, however heat can often be received at a lower level (<85%) in case there is a power outage in the building. Additionally, the system requires water of appropriate quantity and quality, especially after an accident like a pipe rupture. Finally, some of the needed chemicals are by-products from industrial production, which means these chemicals are only available as long as the relevant industrial processes remain in operation. In times of extreme disturbances, such as in war scenarios, industrial operations could potentially be affected leading to uncertainties regarding the supply of chemicals.

In many cases, the district heating companies have agreements regarding delivery times as well as delivery quantities. However, since much of the products come according to Just-In-Time deliveries, there is a growing recognition that agreed delivery times may not be possible to rely on in times of extreme crises. Therefore, work has been launched to set up common pools of reserve materials and products, in particular products with long delivery times (Sinfra, 2025). In general, though, costs related to reserve material and products are a challenge where respondents express a desire of having "preparedness that is also of use during times of normalcy".

### 3.4. *Addressing digital vulnerabilities and cyber threats*

Digitalisation is claimed to be a significant ongoing trend in the district heating sector, where control and monitoring are increasingly digitalised. While accidents can occur, it is the escalating cyber threat that is the main concern. District heating companies face a wide range of cyber threats on a daily basis. Since a wide range of functions are digitalised, there are numerous potential points of intrusion from a malevolent actor. This includes also the interface between the customer/real estate owner and the district heating company.

Strategies to deal with the cyber threat include developing the competence and awareness of all staff categories since cyber attacks often exploit the actions taken by personnel within the organisation. Training and exercising potential scenarios is a key preparedness strategy. Here the focus is both on maintaining system operation through manual routines and on rapidly restoring functionality, including prioritising which digital systems to restore first.

### 3.5. *Maintaining organisational capacity during disruptions*

The organisational capacity, which is anchored in staff competence, is crucial for both normal operations and during disturbances. In particular, the district heating companies are dependent on highly specialised personnel, which creates a vulnerability in cases where disturbances prevent personnel from performing their duties. In scenarios of war or heightened alert, some personnel may have wartime duties outside their own organisation. This makes it crucial to ensure redundancy not only in technical systems, but also in staffing and competencies.

One strategy to maintain and develop competencies and organisational capacities is to conduct regular exercises. In the district heating companies, training and exercises are common practice; however, it is argued that there is a lack of large-scale exercises involving multiple organisations where multi-organisational collaboration and coordination is trained. In addition to developing a common understanding of roles and responsibilities, exercises also create valuable social networks which is crucial when responding to large-scale crises.

### 3.6. *Coordination and collaboration across actors*

Coordination is seen by several respondents as a key towards successful management of disturbances. Previous experiences indicate that collaboration between district heating companies, municipalities, and fire and rescue services generally works well, but often relies on personal networks and trust. However, to assure long term resilience in the context of large-scale disturbances, respondents argue that more formalised collaboration is important. This is particularly important when a broader range of actors need to be involved in a coordinated response. Today, most collaboration is trust-based rather than through formal agreements.

Since district heating is dependent on several other critical infrastructures, especially electric power and water, there are limits to how much security of supply the companies can ensure on their own. Therefore, joint exercises and joint risk assessments are seen as a key to further develop the security of supply.

Coordination with customers, such as real estate owners, is also seen by the respondents as a necessary strategy towards increased resilience. In particular in cases of electric power disruptions respondents claim there are discussions about joint securing of backup power to ensure heat circulation at the customer end, however heat can often be supplied at a lower level (<85%) in case there is a power outage.

### 3.7. *Prioritisation of heat supply during capacity constraints*

The interviews show that prioritisations are often necessary to ensure security of supply, particularly in situations where the generation capacity does not meet demand. Respondents reported that they are well aware of especially critical and sensitive customers, such as hospitals and nursing homes. However, district heating companies have less insight into other types of sensitive customers, such as varying levels of vulnerability in the private housing sector, which raises questions of equity. Here, clearer national guidance is requested.

A related challenge is that it is not always possible to act in accordance with desired prioritisation strategies. This is because the technical configuration of the district heating system is not always designed to allow heat flows to be directed exclusively to prioritised customers while simultaneously reducing supply to non-prioritised customers. In this context, network sectioning is described as a key measure for maximising system performance given existing technical constraints but digital solutions for peak shaving at customer level is a future enable.

Several respondents also describe a prioritisation ladder for extreme situations where operations are scaled down to increasingly focus on the core mission.

### 3.8. *Financial and regulatory conditions shaping security of supply*

Financial drivers are claimed to strongly influence security of supply, sometimes in ways that undermine it. For example, in some cases business strategies push for centralisation of energy generation, such as intensifying the generation to one or a few units while decommissioning smaller ones. Although this typically leads to increased effectiveness, it also creates vulnerabilities as failures, although rare, may give rise to large consequences. Other strategies may optimise systems around a single fuel type, creating dependence on reliable fuel supply and increasing price sensitivity, which in turn heightens vulnerabilities.

Respondents also stress that investments in the district heating are often very expensive and that they are hampered by an unclear, unstable or quickly changing political environment. There are respondents claiming that there is a willingness to improve robustness, but that the right structural conditions are lacking. Therefore, clear and stable long-term regulations at both national and EU levels are considered essential for enabling robust, long-term investment in robustness and resilience.

## 4. Discussion

The findings indicate that developing security of supply in district heating is less a matter of individual technical measures and more a question of managing interdependencies, trade-offs, and organisational capacities across multiple domains. In this section, the results are discussed in relation to previous research on energy security and resilience, with particular attention to how these interdependencies shape local practices and constraints. The findings should be understood as

analytically, capturing recurring and observable patterns in how security of supply is addressed within the Swedish district heating sector, rather than as statistically representative of all district heating actors.

### 4.1. *Challenges for security of supply*

The study identifies a range of challenges in the pursuit of improving security of supply. Many of these challenges stem from the pursuit of day-to-day operational optimisation. Efficiency-driven improvement processes introduce digitalisation, specific technical solutions and global supply chains of fuel and material, which all lead to increased complexity. Since this implies cost reductions and increased profitability, they are of course hard to decline. At the same time, as illustrated in the interview material, the efficiency improvement processes may introduce vulnerabilities which means there is a goal conflict between efficiency and resilience as has been highlighted in the broader energy security literature (Cherp & Jewell, 2014; Hotchkiss & Dane, 2019).

More concretely, digitalisation was described as a process with both benefits and risks. On the one hand, expanded monitoring and control capabilities contribute to increased reliability in day-to-day operations and improved cost efficiency through optimisation. On the other hand, digitalisation exposes district heating systems to new types of digital and cyber-related threats. This means that the nature of security of supply must also evolve, emphasising the need for organisational preparedness, competence development, and the capacity to maintain or re-establish manual operations when necessary.

These trends also intensify external dependencies, meaning that maintaining system operation is not solely within the control of district heating companies. Instead, the security of supply of district heating systems is in fact a joint capability with contributions from multiple actors and systems, in particular the electric power system. The district heating system can, to some extent, maintain operation during external power blackouts, such as through black start capability in combined heat and power plants coupled with installations of back-up power in the distribution system; heat can often be received at a lower level (<85%) in case there is a power outage in the building. However, complete capacity to operate without external power is challenging.

An additional challenge identified in the interview study concerns the need to build organisational capacity. This requires a long-term perspective, as an ongoing generational shift, combined with a reliance on single key individuals, creates vulnerabilities that are difficult to address in the short term. In contrast to technical redundancy, which can often be implemented relatively quickly, organisational redundancy and resilience need to be developed gradually and in a consistent manner, with a particular focus on knowledge transfer within the organisation. This observation is in line with arguments in the broader energy security literature (Goldthau & Sovacool, 2012).

### 4.2. *Needs to improve security of supply*

The interviewees expressed several needs in their pursuit of improved security of supply in the district heating sector. First, there is a growing need to design systems to withstand prolonged and repeated disturbances. Previously, the primary focus has often been on the ability to restart heat generation following short-term disruptions, such as power outages. However, in light of the increased risk of armed conflict, district heating systems increasingly need to be designed to operate under extended periods of severe disruption. Similar needs have also been highlighted in the broader energy security literature (Winzer, 2012).

In Sweden, the government requires that critical societal functions, including the district heating sector, need to be designed keeping in mind a three month long severe war situation in Europe (MSB & Swedish Armed Forces, 2025). Although this in itself is highly challenging, the underlying reason for the three-month limit is that there should be enough time for the critical societal functions to re-organise and transform their operations to a full-scale and prolonged war situation in Europe, with severe implications for Sweden. However, there is currently very little discussion about what can be done now to facilitate the transition from the early phases of wartime operations (first three months), to the more permanent phase (years, multiple years) – something that reasonably should be within the planning sphere considering that the full scale invasion of Ukraine now has been ongoing for more than four years (began 24 February 2022).

Even though it may not be realistic, at this point in time, to develop detailed plans and implement extensive measures for dealing with a prolonged crisis, steps should perhaps be taken now to facilitate such processes to take place if the need for them would arise.

Another need expressed by the respondents is a more detailed and in-depth understanding of external dependencies. Typically, the district heating companies are well aware of their external dependencies at an overall level. However, in the context of prolonged disturbances, wartime situations, etc. it is unclear what consequences can be expected, including cascading effects between societal functions, and ultimately affecting the district heating sector. Not only is additional information and knowledge needed, but also tools to be able to analyse the effects of external dependencies on the district heating system.

Again, the Swedish government and Swedish authorities publish some guidelines and planning assumptions concerning what to expect during wartime situations. For example, all critical societal functions should plan for two weeks of operations completely based on their own resources (MSB & Swedish Armed Forces, 2025), where e.g. the transportation system would be prioritised for army movements. However, there is a need to translate this planning assumption into concrete operational guidance, in particular since the extensive external dependencies for district heating make it questionable whether it is plausible to plan to operate for two weeks without relying on these external systems (power supply, water supply, etc.)

Finally, several respondents highlighted the existence of extensive informal networks among key actors as a current strength, as these networks facilitate collaboration and coordination. At the same time, more formalised forms of collaboration, including joint exercises and shared risk assessments, were described as necessary to ensure long-term resilience in extreme situations such as wartime scenarios. Similar concerns have previously been raised in the literature (Jonsson et al., 2020).

### 4.3. *Methods and measures for development of security of supply*

The interview study reveals that there is a wealth of methods and measures used to develop security of supply in the district heating sector. Overall, there is a mix of formal and informal approaches being used and security of supply can in many cases be seen as an integrated part of everyday activities, rather than as standalone, independent processes with the sole purpose of developing security of supply.

More specifically, the findings indicate that security of supply in district heating is developed through a combination of complementary measures, including the following:

- The creation of redundancy and overcapacity, albeit often associated with high costs.
- Flexibility and diversity in fuel supply and heat generation.
- Emergency stockpiling of critical materials and components, both at the level of individual district heating companies and through shared regional or national reserves.
- Competence development and reduced dependence on single key individuals.
- Exercises that test and validate technical solutions, organisational arrangements, and decision-making processes, particularly those involving multiple organisations, cyber-related scenarios, or situations beyond everyday experience.
- Collaboration and coordination through both informal and formal networks.
- Clear, consistent, and long-term regulatory conditions.

### 4.4. Additional research

There are several areas of further research connected to this paper. In particular, the paper addresses challenges, work processes and needs in relation to the Swedish context. However, in order to advance Swedish practises it is important to learn from experiences in other countries. Therefore, the next phase of the research project where this paper is an output, is to conduct an international comparison, in particular focusing on countries with a high reliance on district heating and at the same time involve in armed conflicts or high levels of threat. Countries such as Ukraine, the Baltic countries and Finland are a few of those we aim to include in the international

outlook. The next phase of the research is then to propose how the security of supply in Swedish district heating can be improved, taking the practical challenges into account. In particular, the focus will be to support decisions of how to determine required levels of security of supply and identify effective means of achieving those levels. This will be done by employing a design research approach where researchers and professionals join together in co-designing and testing potential solutions.

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