SWEET Call 1-2020: SURE

Deliverable report

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Acronyms and abbreviations

DB	Deutsche Bahn
ENTSO-E	European Network of Transmission System Operators for Electricity
HP	Heat pump
HTHP	High Temperature Heat Pumps
GHG	Greenhouse gas
GHGE	Greenhouse gas emissions
IWB	Industrielle Werke Basel
IPH	Industrial Process Heat
OEM	Original equipment manufacturer
ÖBB	Österreichische Bundesbahnen
NG	Natural Gas
PtH	Power-to-Heat
PtG	Power-to-Gas
SFR	Swiss Federal Railway
SFOE	Swiss Federal Office of Energy
SPS	SURE Pathway Scenario
UPS	Uninterruptible power supply

Disclaimer:

This research report utilised generative AI tools for specific tasks, including revising and summarising texts, identifying key topics in the content analysis, and assisting with grammar and clarity checks. Additionally, AI was employed to summarise interview transcripts. However, AI did not produce original research content, data, or conclusions. All substantive findings, interpretations, and analyses are the sole work of the authors. The use of AI was limited to support functions that enhanced readability and organisation without influencing the core research outcomes.

Summary

This research report for deliverable D15.2. examines the adoption potential of decarbonisation options for process heat in Swiss industries, particularly focusing on the chemical sector. The report highlights the critical need for decarbonising process heat in light of the Paris Agreement, which aims for net-zero emissions. It identifies key challenges such as the reliance on fossil fuels and the specific temperature requirements of industrial processes that limit technological options. The document outlines methodologies, including expert interviews and surveys, to assess industry perceptions towards various decarbonisation strategies like the adoption of renewables energies and high-temperature heat pumps.

The findings underscore both the drivers of and barriers to decarbonisation in the Swiss industrial context, providing a comprehensive overview of challenges from the perspective of industry stakeholders. It discusses insights gained from interviews with industry stakeholders and summarises key themes such as energy carriers, barriers, and incentives. Ultimately, the report aims to guide future policy and industry efforts toward achieving substantial reductions in greenhouse gas emissions related to process heat, facilitating a transition to more sustainable practices within the industrial sector.

Zusammenfassung

Dieser Forschungsbericht für das D15.2. untersucht das Potenzial von Dekarbonisierungsoptionen für Prozesswärme in der Schweizer Industrie, wobei der Schwerpunkt auf dem Chemiesektor liegt. Der Bericht unterstreicht die kritische Notwendigkeit der Dekarbonisierung von Prozesswärme im Hinblick auf das Pariser Abkommen, das Netto-Null-Emissionen anstrebt. Er identifiziert zentrale Herausforderungen wie die Abhängigkeit von fossilen Brennstoffen und die spezifischen Temperaturanforderungen von industriellen Prozessen, die die technologischen Optionen einschränken. Das Dokument beschreibt Methoden, einschließlich Experteninterviews und Umfragen, um die Wahrnehmung der Industrie in Bezug auf verschiedene Dekarbonisierungsstrategien wie die Einführung erneuerbarer Energien und Hochtemperaturwärmepumpen zu bewerten.

Die Ergebnisse unterstreichen sowohl die Triebkräfte als auch die Hindernisse für die Dekarbonisierung im Kontext der Schweizer Industrie und bieten einen umfassenden Überblick über die Herausforderungen aus der Sicht der Akteure in der Industrie. Er erörtert die Erkenntnisse aus den Interviews mit den Akteuren der Industrie und fasst Schlüsselthemen wie Energieträger, Barrieren und Anreize zusammen. Letztendlich zielt der Bericht darauf ab, künftige Bemühungen der Politik und der Industrie zu lenken, um eine erhebliche Reduzierung der Treibhausgasemissionen im Zusammenhang mit Prozesswärme zu erreichen und einen Übergang zu nachhaltigeren Praktiken im Industriesektor zu erleichtern.

Résumé

Ce rapport de recherche pour la prestation D15.2. examine le potentiel d'adoption des options de décarbonisation pour la chaleur industrielle dans les industries suisses, en se concentrant particulièrement sur le secteur chimique. Le rapport souligne le besoin critique de décarboniser la chaleur industrielle à la lumière de l'Accord de Paris, qui vise des émissions nettes nulles. Il identifie des défis clés tels que la dépendance aux combustibles fossiles et les exigences de température spécifiques des processus industriels qui limitent les options technologiques. Le document présente des méthodologies, notamment des entretiens avec des experts et des enquêtes, pour évaluer les perceptions de l'industrie à l'égard de diverses stratégies de décarbonisation, telles que l'adoption d'énergies renouvelables et de pompes à chaleur à haute température.

Les résultats soulignent à la fois les moteurs et les obstacles de la décarbonisation dans le contexte industriel suisse, offrant une vue d'ensemble des défis du point de vue des parties prenantes de l'industrie. Le rapport présente les résultats des entretiens avec les acteurs de l'industrie et résume des thèmes clés tels que les vecteurs énergétiques, les obstacles et les mesures incitatives. En fin de compte, le

rapport vise à orienter les efforts futurs des politiques et de l'industrie vers une réduction substantielle des émissions de gaz à effet de serre liées à la chaleur industrielle, facilitant ainsi la transition vers des pratiques plus durables dans le secteur industriel.

Sintesi

Questo rapporto di ricerca per il deliverable D15.2. esamina il potenziale di adozione delle opzioni di decarbonizzazione per il calore di processo nelle industrie svizzere, con particolare attenzione al settore chimico. Il rapporto evidenzia la necessità critica di decarbonizzare il calore di processo alla luce dell'Accordo di Parigi, che mira a emissioni nette pari a zero. Identifica le sfide principali, come la dipendenza dai combustibili fossili e i requisiti specifici di temperatura dei processi industriali che limitano le opzioni tecnologiche. Il documento illustra le metodologie, tra cui interviste a esperti e sondaggi, per valutare le percezioni dell'industria nei confronti di varie strategie di decarbonizzazione, come l'adozione di energie rinnovabili e pompe di calore ad alta temperatura.

I risultati sottolineano sia le spinte che gli ostacoli alla decarbonizzazione nel contesto industriale svizzero, fornendo una panoramica completa delle sfide dal punto di vista degli operatori del settore. Il rapporto analizza le intuizioni ottenute dalle interviste con gli stakeholder del settore e riassume temi chiave come i vettori energetici, le barriere e gli incentivi. In definitiva, il rapporto mira a guidare le politiche future e gli sforzi dell'industria verso il raggiungimento di riduzioni sostanziali delle emissioni di gas serra legate al calore di processo, facilitando la transizione verso pratiche più sostenibili nel settore industriale.

1 Introduction

In light of the Paris Agreement, achieving net-zero emissions is more urgent than ever. A key challenge lies in decarbonising process heat, which significantly contributes to greenhouse gas emissions across various industries. Transitioning from fossil fuels to cleaner alternatives, such as heat electrification, high-temperature heat pumps, and renewable gases, is essential for meeting sustainability targets.

For several reasons, decarbonising the industrial process heat sector is a challenge. Specific needs arising from industrial processes, particularly temperature levels, limit the technological Options. Industrial companies mainly produce intermediate and non-name goods embedded in highly competitive markets. Thus, we assume that their decisions are mainly cost-driven, though varying across companies, and that they hardly have an extra willingness to pay for environmentally preferred energy sources or energy-efficiency options. In contrast to the situation in the electricity and building sector, policy instruments such as subsidies have yet to target the industrial sector effectively.

This deliverable explores the acceptance and adoption potential of these decarbonisation options within the industrial sector by identifying barriers, needs, and drivers for change. Furthermore, we provide insights into the status quo, i.e., to what extent decarbonisation has already been dealt with. We do this through a mixed-methods approach using interviews and surveys with industry stakeholders and experts. In this preliminary deliverable, the survey methods are covered, and the results are presented from the perspective of the interviewee sample. In a future amendment, the survey results will complete the overarching task and contribute the perspective from a broader sample of companies.

The deliverable is a report embedded in the SURE work package 15 (WP15). The overarching goal of WP is to provide insights that facilitate the Swiss industry's transition to a more sustainable energy future. For this, a focus on the chemical and pharmaceutical industries has been chosen due to their high-temperature process heat demand and relevance to the energy demand in Switzerland. In addition, a regional focus on Basel has been chosen due to the relevance of these industries in that region and the co-funding from Industrielle Werke Basel (IWB).

2 Background

In the background, we highlight the current policy context and provide a selection of recent studies on process heat decarbonisation.

2.1 However, we do not claim this to be a comprehensive literature overview. Policy context and drivers

The policy context may be a significant driver in industries' decarbonisation efforts. Here, we highlight the ones in Switzerland and global initiatives relevant to Swiss-based companies.

2.1.1 in Switzerland

Energy policy in Switzerland offers various instruments and support schemes for industrial companies to decarbonise their production. These instruments, which companies implement through consultancies such as EnAW, include the target agreements ("Zielvereinbarungen"), energy consumption analyses (ECA, Energieverbrauchsanalyse (EVA)), and decarbonisation roadmaps (BAFU, 2024b; EnAW, 2024). According to Swiss law, adopting target agreements or ECA is mandatory for large consumers.

The Swiss Emission Trading System (ETS) regulates the emissions from the most GHG-emitting industrial installations and aims for a cost-effective reduction of GHG emissions. Companies in aviation and emission-intensive sectors, such as those producing paper, cement, ammonia or manufacturing with glass, metal, and ceramics, must participate in the ETS. Which companies are required to join the ETS, and which companies are exempt are regulated in the CO2-Ordinance. The ETS also includes possibilities to join the system voluntarily, a so-called "opt-in", and for companies whose emissions at a production site permanently fall under 25'000 t CO2 equivalents, there is an option to be exempt from the ETS, a so-called "opt-out". The "opt-in/- out" options are regulated in the CO2 Ordinance (Federal Office for the Environment, 2020; Federal Office for the Environment, 2024).

The ETS is a quantity control instrument applying the "cap-and-trade" principle. Each year, the maximum amount of emissions for all ETS participants is defined and introduced to the ETS as emission allowance certificates. Emission allowances must cover all emissions from a production site. Since 2010, the total emission allowances have been reduced each year by 1.74% (from 2013-2021) and 2.2% (from 2021 onwards) of the original baseline.

With the acceptance of a partial revision of the CO2-Law in 2019, the ETS has been extended indefinitely and is compatible with the EU's ETS since 2020. Since 2022, market stabilisation instruments have been introduced to limit available allowances. The FOEN calculates the number of allowances free of charge for each participant using benchmarks. These allowances can be traded between the participants in case of an allowance surplus or shortage.

The Swiss "Klima—und Innovationsgesetz" (Climate and Innovation Act) mandates a 90% reduction in industrial emissions by 2050 compared to 1990 levels and requires all companies to achieve net-zero emissions by 2050. These efforts reflect the increasing global focus on corporate responsibility for direct and indirect emissions, reinforcing the industry's role in achieving climate targets.

2.1.2 Global and European Policy Focus

Process decarbonisation in the industry may be increasingly driven by frameworks like the EU Taxonomy, ESG (Environmental, Social, Governance) metrics, and Science-Based Targets (SBTi). The EU Taxonomy provides clear guidelines for identifying and financing sustainable activities, pushing industries towards greener technologies. ESG metrics, particularly in the environmental pillar, emphasise the reduction of emissions and energy use, aligning financial success with sustainability. Meanwhile, SBTi encourages companies to set scientifically aligned emission reduction targets, fostering innovation in low-carbon processes. Together, these frameworks can accelerate the transition to a sustainable industrial future.

Furthermore, the EU Emission Trading System (EU-ETS) is a key policy tool in driving process decarbonisation in industry. It sets a cap on total greenhouse gas emissions from high-emitting sectors, including power generation, heavy industry, and aviation, and allows companies to trade emission allowances. The EU-ETS encourages companies to adopt cleaner technologies to reduce emissions by progressively lowering the cap. This market-based mechanism directly incentivises decarbonisation by making carbon-intensive processes more expensive, pushing industries toward more sustainable operations. The Swiss- and EU-ETSs were linked in an agreement that entered into effect on 1.1.2020. As a part of the agreement aviation and fossil power plants can now enter the Swiss ETS, so the two systems act in accordance. Participants of one trading system can now trade in the other.

2.2 Challenges and Adoption Potential

2.2.1 Drivers and acceptance of decarbonisation in industry Switzerland

Companies consider decarbonisation important for their business success or are mandated to act upon it, as over 4,000 work with organisations such as the EnAW to develop decarbonisation strategies. Key drivers include concerns about potentially significant revenue losses due to regulations, fines, and missed business opportunities. However, challenges such as a lack of awareness, insufficient knowledge of available tools, and the high complexity of the subject hinder progress (Source Klimastandort Schweiz); thus, it is essential to understand these challenges.

In the Swiss context, there are only a few studies on the challenges to adopting alternative decarbonisation options, such as fuel substitution, alternative energy sources or electrification of process heat

(Rehfeldt et al., 2018). One notable one is based on interviews with Swiss industry firms, exploring factors that hinder or accelerate the adoption of decarbonisation technologies to inform more effective policy development (Hafner, Speich, Bischofberger, & Ulli-Beer, 2022). They identify key barriers to adopting decarbonisation technologies in the Swiss industrial sector: technological uncertainty and long payback periods.

Kiemel et al. (2023) highlight the growing importance of integrating environmental management into corporate strategies due to the increasing impacts of climate change and the urgency driven by recent political and military conflicts. Despite the ambitious emission reduction goals set by many companies, the industrial sector remains highly heterogeneous in terms of emission intensity. A survey of 186 companies in the Germany-Austria-Switzerland region reveals that while many companies set high targets, 41% invest only in low to medium efforts and often require external support. The paper provides over 116 best practices for reducing emissions, offering a guideline for companies to meet their climate goals and serving as a benchmark for other regions and sectors.

2.2.2 General challenges from a comparative perspective

A recent review indicates a notable gap in energy-related research focused on the industrial sector (Verwiebe, Seim, Burges, Schulz, & Müller-Kirchenbauer, 2021). Despite interest in modelling industrial efficiency targets and new technology adoption, the lack of publicly available data and reluctance to publish such research have limited the number of studies. Our study aims to address these gaps and contribute to a better understanding of the industry's decarbonisation needs by capturing the stakeholders' views.

The literature identifies key challenges and factors influencing industrial decarbonisation. A study with a Scandinavian focus, which is based on interviews with 50 energy-intensive industries, reveals four common narratives: scepticism about technological solutions, calls for more active policymaking, concerns over trade-offs between climate goals and other social/environmental objectives, and systemic weaknesses in technology development and diffusion (Steen et al., 2024). The study emphasises that decarbonisation relies heavily on expanding electricity supply and distribution, a challenge likely applicable in other countries, including Switzerland. On the other hand, the risk-return potential and positive side effects of decarbonisation measures are key drivers. The study also concludes that policy measures beyond carbon pricing are essential for a successful transition.

McMillan and Wachs (2024) discuss the main challenges in decarbonising Industrial Process Heat (IPH) in the industrial sector based on a survey of 12 American industries. Three key obstacles were identified: lack of identity, lack of systematicity, and uncertain system dynamics. The "lack of identity" refers to the fact that the ideal decarbonisation method depends on the specific technical requirements (e.g., temperature, pressure) and location factors (e.g., fuel availability) of each industrial process, making it challenging to find one-size-fits-all solutions. The "lack of systematicity" highlights that each plant is unique, and creating effective decarbonisation alternatives requires custom-designed solutions, adding time and costs. Uncertain system dynamics arise from these complexities, leading to challenges in stakeholder decision-making. Some stakeholders view decarbonisation as a collective industry issue, while others take a more proactive, collaborative approach with technology developers.

The authors suggest that cross-cutting decision-making strategies and standardised evaluation methods are needed to overcome these challenges, to streamline the process and reduce complexities. This would help accelerate the adoption of decarbonisation technologies across different industries. Further research is recommended to understand specific drivers and needs, which we address for the regional contexts in Swiss industrial sectors.

Other authors have explored the maturity of current technologies for the process of decarbonisation (Gailani, 2024). The study found that the industrial sector, responsible for approximately 25% of global CO2 emissions and 38% of final energy use, could achieve substantial emission reductions through a mix of decarbonisation strategies, especially in the context of process heat. The study highlights that using a combination of mature technologies like carbon capture and storage (CCS), hydrogen and biomass fuel switching, and energy efficiency improvements could mitigate around 85% of emissions in most sectors. However, full decarbonisation of energy-intensive and high-temperature processes may require advancements in technology maturity.

3 Scope and Case Study Overview

3.1.1 Scope

Our research centres on the manufacturing industry in Basel-Stadt, Basel-Land, and neighbouring cantons within IWB's supply area. The primary focus is on chemical, pharmaceutical, and food industries due to their significant process heat demands. We conducted interviews mainly with companies in Basel, while also incorporating expert interviews for broader insights. To expand our geographical scope, the upcoming survey will include companies from other Swiss cantons, though responses are expected primarily from the Basel region due to the high industry density there.

3.1.2 Relevance of the industrial sector, processes and heat decarbonisation

Although industrial sector GHG emissions in Switzerland have been gradually declining since the previous decade, their total emissions in 2022 still amounted to 9.64 Mio. t CO2eq, which is a share of the total emission of 23.1% (BAFU, 2024a). A considerable share of these emissions is due to process heat. For an in-depth overview of the relevance of industrial heat and decarbonisation, see the previous deliverable D15.1 (Jakob, Melliger, Bagemihl, & Talary, 2023).

Previous literature has investigated the potential of HTHP in the food and beverage and paper and pulp industries (Obrist, Kannan, McKenna, Schmidt, & Kober, 2023). While these industries have a high potential to adopt HTHP due to their typical process heat demand below 200°C, our case expands this scope to the chemical and pharmaceutical industries (while still covering other industries). The chemical and pharmaceutical industries are strongly represented in the area of Basel, where several large companies are located. These companies have a high relevance in terms of economic and energetic activity.

3.1.3 Scope of study in the chemical industries and significance

According to the regional To define the scope and show its relevance for our study, we present statistical data on companies in the Basel region and surrounding cantons. The descriptive assessment is based on STATENT and STAGRE from the Federal Statistical Office (BFS, 2022). Alongside the energy-related considerations explored in Section 3.1.2, this data provides a comprehensive understanding of the region's and sector's economic and industrial significance.

Industrial companies in the region of Basel represent only 9% of the total businesses. However, their economic and employment impact is significant. According to the data, 171 industrial companies in this region employ nearly 30% of the total industrial workforce, indicating their large scale and significance for our case study. The pharmaceutical industry, in particular, stands out as the dominant sector in Basel, especially in Basel-Stadt, where it plays a crucial role within the broader chemical industry. This regional analysis provides insights into the economic importance and the potential for sustainable transitions within the sector.

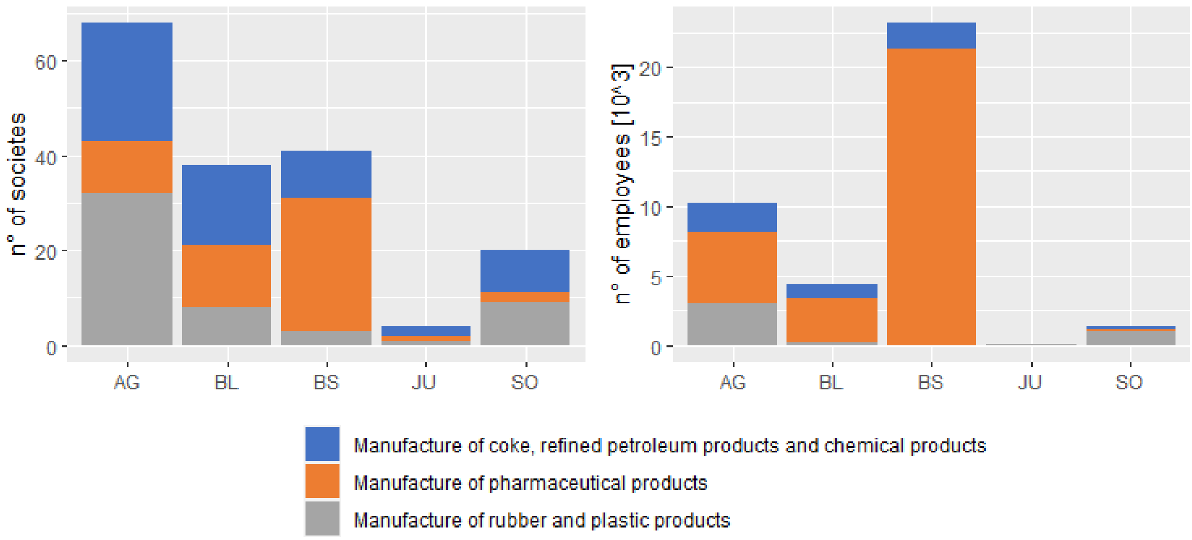

Figure 1 Bar charts showing the distribution of companies (societies) and employees across subsectors and cantons within the chemical and pharmaceutical industries, highlighting production branches (BFS, 2022). Cantons represent the Basel scope and neighbouring cantons within IWB's supply area.

4 Methodology

This study employs a mixed-method approach, combining statistical population evaluations, expert interviews, and a survey to explore the decarbonisation process across industries comprehensively. By integrating these methods, the research captures a broad understanding of strategic considerations, specific issues, and implementation barriers. The semi-structured interviews are explorative and provide an in-depth, context-specific view of the industry about challenges and needs. Through coding, this qualitative data is systematically analysed to identify recurring themes, barriers, and drivers, facilitating comparisons and the identification of major themes and concerns. Meanwhile, the survey offers both qualitative and quantitative insights from a larger and potentially more generalisable sample to explore current process decarbonisation efforts, adoption potentials, challenges and needs.

While the interviews have already been conducted and analysed, the survey has not been launched at the time of writing this deliverable. Instead, the survey method has been refined and builds on the insights from the interviews and the internal reviews of this document.

4.1 Interviews

4.1.1 Exploratory expert interviews and interview guideline validation

Interviews with experts and peers are essential to gain a broad and overarching understanding of the current state and potential in the industry regarding decarbonisation. In the context of this research project, we held preparatory interviews with three experts in either an open or semi-structured form. These experts were either peers working as scientists or consultants, one war part in SWEET, and specialising in topics such as solar-thermal energy, heating and geothermal systems or industrial decarbonisation. In addition, we contributed our expertise in the field. In addition, some of these experts were asked to provide feedback on the interview guidelines, which helped define the scope of the upcoming semi-structured interviews with the stakeholders in the industry.

4.1.2 Interview guideline

The semi-structured interviews aim to assess the current perception and progress of decarbonising process heat in the manufacturing industry. For this purpose, technical managers of primary industries (energy consumers) are approached. A guideline was the basis of the interview, but the discussion can develop further and deviate from this precast form. Our goal is to learn more about their "starting point in the decarbonisation process", which translates to processes and technologies they have implemented at the moment (e.g., current energy source and needed temperature), considerations on their side of how to decarbonise their process, the constraints and drivers they face in these considerations and the role of energy providers in these thought processes. Table 1 further explains the reasoning for inquiring about specific topics and questions.

Table 1 Overview of interview guideline.

Topic	Type of questions	Reasoning
Status Quo	Technical details about processes, temperature, energy carriers and sources.	- Knowledge about the current infrastructure sets the basis for a productive discussion about the companies' perceptions and considerations. - Characterisation of sample to generalise/contextualise findings.
Approach to decarbonisation	Role of instruments, current considerations and projects, priorities for energy carrier, and support	To gain knowledge on the role of instruments and initiatives, why projects have been implemented, what kind of gains (if any) are expected from the projects, which technologies are currently appealing to the company and what kind of further assistance the companies wish for.
Barriers and boundary conditions	Open questions about barriers to include renewable and high-temperature heat pumps. Focus also on economic and technical challenges.	Knowledge about barriers is essential information for policymakers and service companies.
Resilience and Flexibility	Are supply security, risk-hedging, and resilience major points of consideration for companies?	- Potential barrier and boundary condition (see above). - Tie into the central question of the SURE project
Role of energy suppliers	Explore the role of energy suppliers in decarbonisation.	

4.1.3 Interview sampling

For our interviews, we sampled participants around Basel who act in roles tied to process energy. This also includes energy service providers that do not directly produce goods but provide infrastructure and energy for manufacturers. In the final sample, we have three representatives: a heating contractor, a pharmaceutical company, and a food and beverage company. We have contacted these representatives through telephone inquiries and declared with a participation sheet the scope and data used in the study (We report an anonymised and aggregated form of the result).

4.1.4 Analysis of interviews – Summaries and content analysis

The analysis of the interviews followed a mixed methods approach and was done in three steps.

Step 1: Transcriptions

To analyse the semi-structured interviews, we first transcribed them. If the interview was in Swiss German, we translated it to High German. The transcription provided a basis for the summary, content analysis, and survey design. In a second step, we anonymised the transcripts for further AI analysis by removing the names of people, companies, and specific locations to adhere to our privacy declarations.

Step 3: Summaries

In a second step, we summarised the anonymised interviews with the assistance of AI technology (OpenAI paid Account) to capture the essence of the interviews, facts, and essential topics. We used the GPT-4o Model and the following prompt: "Summarise this interview to capture the most important points regarding process heat decarbonisation." To ensure accuracy, we compared the resulting outputs to the original manuscript.

Step 3: Content Analysis

In the third step, after becoming thoroughly familiar with the interview content, we conducted a content analysis (Columbia University, 2024). This method allowed us to dig deeper into the interviews by quantifying and analysing the presence and meaning of specific words, phrases, or themes. Compared to manual evaluation, this process provides more systematic and reproducible results.

The conceptual content analysis enabled us to identify keywords and concepts used in the questionnaire, highlighting their importance to stakeholders and revealing differences between them. Additionally, this method allowed us to evaluate what was not mentioned in the interviews, offering insights into potential gaps in awareness or priorities. This, in turn, helped us to address the following research questions better:

- **What renewable energy carriers are stakeholders aware of to decarbonise production?**
- **How do stakeholders perceive the progress of decarbonisation efforts?**
- **What are the barriers to decarbonisation?**
- **What actions and incentives could drive further progress in decarbonisation?**

The conceptual content analysis breaks down the interview text into codes, representing manageable analysis categories. These codes capture themes, subjects, and meanings. For example, codes could include "financial barriers" or "technology readiness," which allow for more targeted analysis. These codes are the foundation for deeper analysis and comparison (Columbia University, 2024).

The conceptual analysis in our study followed a structured and systematic approach, ensuring consistency and thoroughness. The key steps are outlined below:

1. **Level of analysis:** For energy carriers, analysis was conducted word-by-word using a predefined set of codes. Broader phrases and concepts were coded for the themes of *current state, barriers, and incentives*. Here, the coding was flexible, allowing new codes to be added as themes emerged.

2. **Coding content:** The frequency of themes was tracked to determine the relative importance of topics to stakeholders. Coding focused on the broader meaning of responses rather than individual word choices, particularly in the current state and barriers, allowing for more nuanced interpretation. Filler words and extraneous information were excluded to focus on meaningful content.

3. **Coding process:** Two researchers initially coded the interviews using predefined and exploratory codes. This process was iterative, involving multiple rounds of review across interviews as new codes emerged. The research questions guided the selection of codes. Sentences with

multiple themes were tagged with several codes. For easier identification of barriers and incentives, we also used the AI functions of “ATLAS.ti” to look for specific parts in the texts.

4. **Comparison and quality check:** To increase reliability and consistency, we first reviewed the resulting codings. This process involved verifying whether the applied codes accurately represented the interview content, resolving discrepancies through discussion, and refining or merging related codes where necessary (e.g., combining "payback times" and "financial viability" into a broader category). In the second step, we compared the coding of both researchers. Differences were analysed and merged.

5. **Theme analysis:** The identified themes were analysed with the research questions in mind. The themes were categorised based on frequency and relevance. Recurring and unexpected themes were discussed, interpreting them within the context of the responses and the broader study framework.

6. **Comparison between interviews:** A comparative analysis was conducted to assess the presence or absence of themes across interviews. Key questions guiding this comparison included: Which topics unexpectedly did or did not emerge in different interviews? What were the common themes across interviews? As the same semi-structured interview guide was used throughout, these comparisons highlighted the specific focus areas of each interview.

4.2 Survey

Based on insights from expert interviews, we designed a survey to capture the perspectives of a larger sample of companies. The survey focuses on the current state of decarbonisation, the processes firms are engaged in, and the key considerations influencing their decision-making. It also explores both the barriers and drivers that impact decarbonisation efforts.

The survey aims to identify the specific needs companies face in overcoming these obstacles, which will inform policy recommendations tailored to these challenges.

4.2.1 Sampling process

To gather data, a multi-pronged sampling approach was employed, combining several methods to maximise participation. The sampling method is not randomised but aims at capturing a broad sample of companies representing :

- Contacts from Previous Interviews: Existing contacts established during prior interviews were re-engaged and asked to participate in the survey, ensuring the continuity of insights from previously consulted experts.

- Pharmaceutical Industry Association (scienceindustries): The survey was distributed through a pharmaceutical industry association, utilising their network to reach key stakeholders within this significant sector.

- Direct Outreach in the Food Industry: We took a targeted approach to the food industry, contacting companies via phone to assess their interest in participating. The contact details for these companies were sourced from publicly available information online.

- We also inquired whether companies utilise heat, which led to the selection of relevant companies.

- Snowball Sampling Technique: To expand the survey's reach, a snowball approach was used, encouraging respondents to refer other relevant companies within their networks.

This comprehensive sampling strategy ensures diverse and robust data collection, aligning with the broader scope discussed in Section 3.1.1, capturing insights into the decarbonisation of processes in the chemical, pharmaceutical and food industries.

4.2.2 Structure of the Survey

The survey is structured into several key sections (See amendment for the entire survey)

1. **General relevance and company data.** Evaluate the company's relevance to our study. Those without process heat demand are redirected to the end of the survey.

2. **Firmographics:** This section assesses firmographics and the interviewee's professional experience. These include sector, size and embeddedness in international groups and are used as explanatory variables later.

3. **Processes**: We inquired about the number of processes. Based on the answers, we designed the upcoming survey, only asking about the 1-2 energetic most relevant processes in specifics and other energetic processes in general. For each process, there is a section about process details.

4. **Current stage in the decarbonisation process.** Firms are at different stages of the decarbonisation journey. The survey follows a decision-tree model, guiding respondents through identifying decarbonisation needs. Based on the actions taken so far (see flow logic below in Figure 2), respondents are redirected to the section about barriers, challenges, and opportunities.

    1. **Not starting to look into options -> Obstacles**: This section identifies the specific obstacles that have prevented a company from starting to assess decarbonisation options.

    2. **(Looked at options but did not implement options barriers)** -> Barriers Section -> This section identifies the specific barriers companies have faced (e.g. Technological, economic and organisational barriers)

    3. Partly or fully implemented decarbonisation options: Explores challenges and potential opportunities arise progress.

5. **Drivers of decarbonisation**: This section explores common drivers and their relevance for the company (see, e.g., policy drivers (see 2.1) or other drivers, such as customer expectations).

6. **Need**: What do companies need from the state and suppliers to decarbonise in the future?

7. **End of survey**: Inquiry about interest in more information, pilot projects, or other contacts (snowballing).

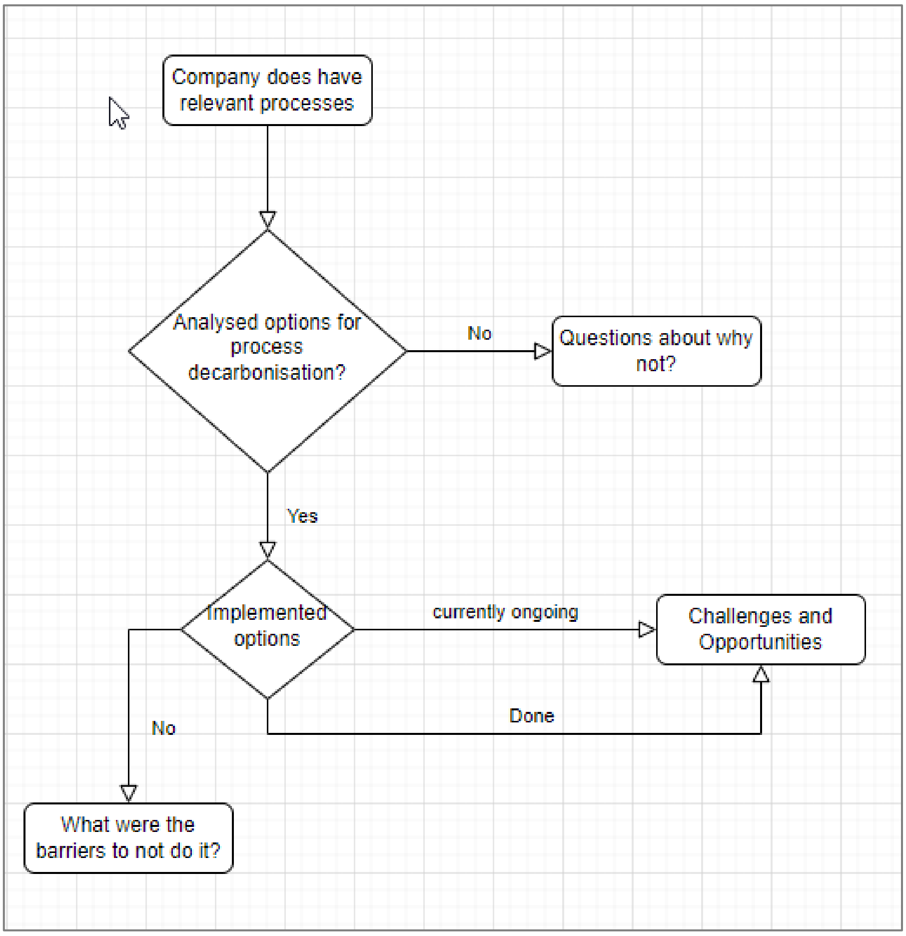

Figure 2   Flowchart of the current progress section.

4.2.3   Analysis of the survey

In this study, a descriptive analysis examines the survey responses. Frequency distributions for each question are calculated to assess the number and percentage of participants selecting each response. Explanatory variables assessed in the survey are used to recognise potential trends in the group. For numerical data, such as years of experience, the mean and median are computed to summarise central tendencies. Visual representations, including bar charts and pie charts, are created to illustrate key trends and facilitate interpreting the results.

The analysis of critical findings focuses on identifying significant patterns and trends within the data. Common responses are highlighted, and basic comparisons between respondent subgroups, such as differences based on the decarbonisation progress and the process heat temperature, are relevant.

5 Preliminary Results and Discussion

The following results reveal key concerns, current considerations, the focus of three companies in the chemical, pharma and food industries, and expert insights. The analysis of the online survey follows in the addendum to this report.

5.1 Interviews with peers

Expert-1 explained that for the producing industry, the main concern in the context of process heat production is, on the other hand, the security of supply and redundancy and, on the other hand, the storage of heat. Expert-1 mentioned soil regeneration due to heat extraction by heat pumps and seasonal storage in reservoirs as potential solutions. The expert considers decarbonisation roadmaps (such as the ones offered by EnAW) important instruments. In addition, the expert highlighted the influence and expectations of customers as a relevant driver for the decarbonisation efforts of industrial operations.

Following the review of our interview guideline and the introduction to the project, Expert-2 concludes “The companies you are targeting have been dealing with GHG emissions and their reduction for a long time (exemption from the CO2 levy, participation in the emissions trading system ETS). Complete decarbonisation, on the other hand, is likely to be a huge challenge.”

Expert-3 focused on the research of solar thermal solutions. According to the export, the decarbonisation of industrial heat using solar thermal technology faces several integration and feasibility challenges. Solar thermal systems are often considered supplementary to high-temperature heat pumps (HTHPs) to achieve necessary temperature levels. However, concerns about these systems' flexibility and economic viability remain, particularly due to variable solar production, with only approximately 1000 hours of viable solar radiation annually. Large heat storage solutions, such as pit storage, could help address heat availability for the industry. Interest in solar thermal solutions varies across industries, with some pilot projects existing. However, market penetration remains limited due to a lack of large-scale pilot projects. Infrastructure providers are collaborating with industrial partners to assess heat availability and distribution needs.

A fourth and extensive interview has been held with a food consultant, and the results will be added to the addendum to this deliverable.

5.2 Interviews with the industry

5.2.1 Overview of interviewees

Of the ten potential companies that we contacted, only three were able or willing to participate in our interview. These three can be classified as medium—to large companies representing the pharma, chemical, and food industries. Table 2 summarises the general characteristics of the companies.

Table 2 Overview of interviews

Company ID	Industry	Company Size	Locations
Company A	Pharmaceutics	Large and international	Basel, several sites
Company B	Beverages	Medium, mostly local but global group	Several
Company C	Heat service proved	Medium, larger international group.	Global group but interview specific to the location in Basel

5.2.2 Summary of semi-structured interviews

The tables below summarise the key topics discussed during the interviews. These include both technical insights as well as marketing and strategy-related statements. While the tables offer a helpful summary of the topics discussed to understand single case studies and provide inputs for the survey, it is important to note that the perspectives provided are subjective and company-specific. As such, these findings may not fully represent general industry trends or be broadly applicable to other companies. Hence, we will conduct a survey with a broader number of companies to enhance the generalizability of these insights.

Table 3 Overview of the major topics of Company A

Major Topic	Summary
Core strategy and organisation	The company is focused on decarbonising energy and process heat at its major sites. Each large site has its CO_2 roadmap, which aligns with global corporate goals and facilitates the exchange of best practices across locations. The company operates with a holistic approach, integrating strategy, tactical implementation, and operational execution for energy management, including investments in projects that span from strategy to day-to-day operations.
Separation of temperature in heat systems	A key part of the energy concept is the separation of high-temperature and low-temperature heat systems. High temperatures (165°C) are used only where necessary, such as for specific production processes, while lower temperatures (40°C) are used for other functions, including room heating. The "heat separation process" is a complex transition that requires retrofitting existing buildings and upgrading HVAC systems to reduce reliance on steam systems, especially in office, laboratory, and production buildings.
Use of Biomass for High-Temperature Heat	The company has implemented a biomass heating system at the Basel site that uses local wood chips to generate high-temperature heat (165°C) for processes like steam production. Furthermore, the company aims to minimise biomass use and ensure its local sourcing within a 50 km radius to maintain ecological sustainability.
Role of Heat Pumps	Heat pumps, especially high-temperature heat pumps (HTWP), play a significant role in their energy concept. These are seen as scalable technologies for decarbonisation, but current solutions are still in the pilot phase. The company is leading efforts to develop HTWP technology for industrial use. Current systems leverage waste heat, groundwater, and river water as heat sources for their low-temperature networks, optimising energy efficiency by coupling heating and cooling.
Innovation and Technology Development	The company has a history of pioneering natural refrigerants, namely CO_2. They are focused on using natural refrigerants for high-temperature applications. Despite market and supplier challenges, they believe that pilot projects and real-world testing will

	drive the development and adoption of high-temperature heat pumps.
Energy Efficiency and Lifecycle Thinking	The company aims to reduce energy consumption and increase efficiency across sites. For example, they focus on energy-efficient designs for new buildings and upgrades for existing ones to optimise long-term performance. PV provides some energy savings but can only cover some of their sites' energy needs. They highlight that replacing all assets is not practical; instead, they innovate by thinking about energy systems differently, such as implementing site-wide energy solutions that improve efficiency and reduce capital expenditure.
Challenges with Scaling and Flexibility	One of the primary challenges is integrating decarbonised systems into existing production environments, which have stringent regulatory and operational requirements (e.g. GMP). With future HTWP (currently in pilot phases), they aim to create flexible heating systems that meet varying temperature requirements at different production stages. The goal is to maintain a centralised temperature system (currently set at 165°C) that meets the needs of most processes.
Government Support and Collaboration	The company highlights its interest in tapping government support through the Climate and Innovation Law (KIG) to help finance innovative decarbonisation projects. It is actively involved in industry collaborations to share best practices and drive progress in decarbonisation efforts across the sector.
Long-Term Sustainability and Financial Viability	Sustainability is deeply embedded in the company's culture. They focus on long-term goals rather than short-term financial gains, seeing decarbonisation as a long-term investment. The company takes a long-term view on payback periods, especially for sustainability-related infrastructure projects, extending beyond the typical five-year horizon.

Table 4 Overview of the major topics of Company B

Major Topic	Summary
Current Energy Use	The company operates multiple production sites, including a brewery and soft drink bottling plant, with a heat demand of around 35 GWh and an electricity demand of around 15 GWh. Approximately two-thirds of their heat demand is covered by renewable energy.
Renewable Energy Sources	The brewery generates energy from fermenting organic matter in wastewater and concentrates alcohol removed from non-alcoholic beer. This alcohol is used as a fuel substitute for gas and oil. The company relies on natural gas for most of its fossil fuel use, with some heating oil for peak loads.
Heat Recovery and Heat Pumps	Heat pumps are used in some processes, such as the pasteurisation of cans and beverages, where heat from compressed air systems is recovered. However,

	due to cost constraints, the pumps cannot be custom-designed. The system utilises low-temperature waste heat and boosts it for use in the process. They have faced challenges with dynamic temperature fluctuations in processes, which affect the efficiency and modulation of heat pumps.
Challenges in Efficiency and Costs	Economic viability remains a concern. While the company aims for decarbonisation, it must manage costs carefully, particularly given volatile energy prices.
Future Projects	The company is exploring additional renewable energy sources, including a new woodchip-fired boiler, to reduce reliance on fossil fuels. They are targeting over 90% renewable energy use by 2030 (also using guarantees of origin).
Complexity of Regulations and Market Forces	Regulatory uncertainty, particularly around CO2 emissions reduction and renewable energy targets, complicates long-term planning.
Demands by customers	The company faces increasing demands from retail partners regarding sustainability topics. These inquiries are deemed benign, but they expect an increasing need to deliver hard facts about sustainability efforts.
Circular Economy and Reuse of Packaging	The company is concerned about the sustainability of the return system for reusable glass bottles. They argue that the current system in Switzerland needs more incentives for retailers to support reusable packaging.
CO2 Neutrality Goals	Their parent company has set ambitious sustainability goals, like achieving CO2-neutral production, which influences decisions regarding investments in energy infrastructure at their company.

Table 5 Overview of the major topics of Company C

Major Topic	Summary
Energy Source and Process	The companies' industrial park generates steam by burning solvent waste, which customers then use for process heat, creating a closed-loop system. This steam is produced at various temperatures and pressure levels, with some excess steam converted into electricity during lower-demand periods.
Steam Supply and Demand	Customers require different steam temperatures and pressure levels, primarily 240°C at 15 bar for higher-temperature needs and 180°C at 5 bar for comfort and solvent regeneration. The park has additional natural gas boilers for peak loads and redundancy.
Economic Decarbonization Challenges	First, the facility's energy production largely involves fixed personnel and maintenance costs, making cost flexibility challenging. Second, potential efficiency improvements would reduce revenue for the internal energy supplier.
Customer Pressure and Barriers	Clients prefer sustainable solutions but often prioritise cost-effectiveness over carbon neutrality, complicating investments in greener technologies.
Options for Process Heat Electrification	The facility is exploring using heat pumps (HP) for comfort heating, which can also reduce demand on the main process heat system. However, high costs

	and uncertain future grid tariffs for electricity make fully electric systems less appealing without subsidies or pilot projects.
Clearance and Taxation Regulation	The company representative views the clearance regulations as a regulatory barrier. Swiss policies tax biogas imported via pipelines but exempt ISO container imports. This discrepancy disadvantages renewable fuels, creating a protectionist effect that raises costs and complicates the adoption of sustainable alternatives for process heat.

5.3 Results of the content analysis

The three semi-structured interviews with the industrial stakeholders form the basis for this content analysis. The results refer to the questions posed in Section 4.1.4 and cover the status quo, energy carriers, barriers and incentives.

5.3.1 Occurrence of energy carriers and status quo

In the initial phase of the analysis, the energy carriers were examined to provide an overview of the interview's focus (Figure 3). The primary emphasis of the discussion was on the potential of high-temperature heat pumps (HTHP) and the alternative Biogas and Wood. Other energy carriers were considered, but their significance was comparatively minor. For example, hydrogen and district heating supply are rarely considered, while thermal solar was never mentioned (only PV for electricity provision).

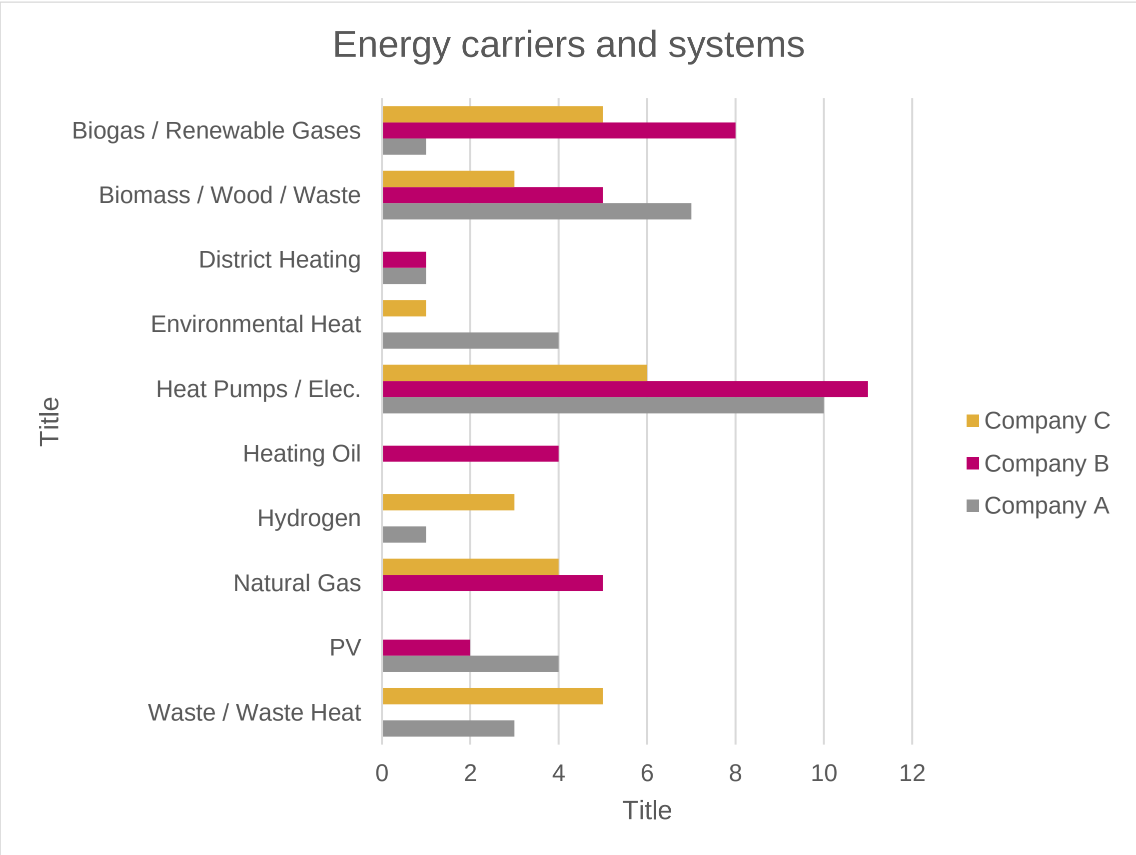

Figure 3 Comparison of energy carriers. Results are based on three interviews, coding from two researchers and are aggregated into major categories.

Furthermore, the analysis of the status quo shows that all three companies are in the process of decarbonisation but to different degrees, ranging from first ideas and talks to decarbonise some part of their production to concrete plans or the notion that their production is already partly decarbonised.

5.3.2 Occurrence of Barriers and Incentives

In the interviews, the major barriers to decarbonisation were unanimously identified as economic and technological viability (Figure 4). This includes the high energy costs of alternative energy carriers or the high investment costs of new technologies, which highlights the importance of these aspects for the companies. The current state of technology is often a concern, mainly related to heat pumps, but the temperature profiles of alternative energy carriers (such as wood) were also mentioned.

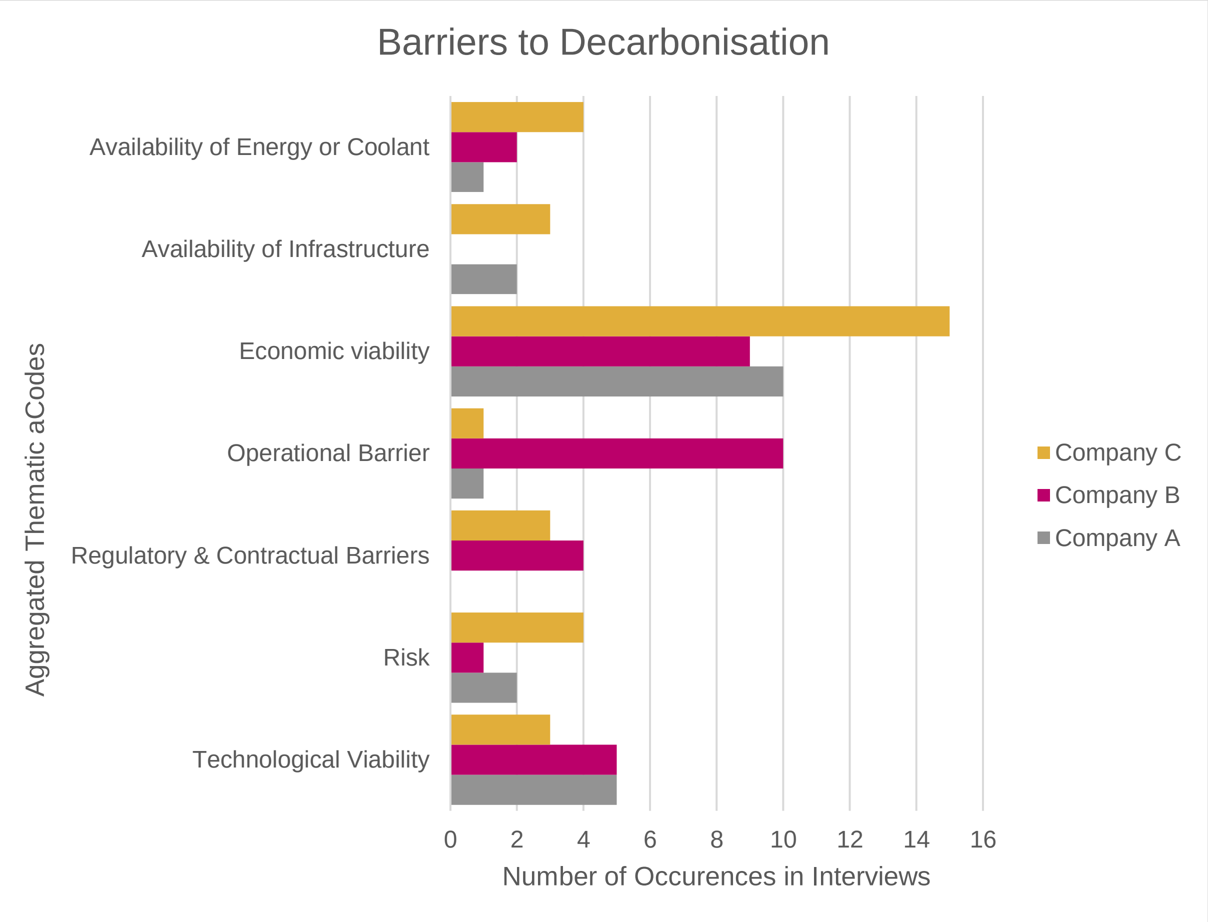

Figure 4 Comparison of aggregated occurrences of codes about decarbonisation barriers. Results are based on three interviews, coding from two researchers and are aggregated into major categories.

Furthermore, the availability of infrastructure (e.g. hydrogen pipelines) and suitable and sustainable coolants for heat pumps or local wood and biogas are concerns. Operational barriers have mainly been identified in Company B, e.g., space availability. Regarding regulations, the interviewee criticised different policies, e.g. current EU legislation (renewable energy targets, circular economy requirements) or border taxation laws.

Compared to the barriers, the needs and incentives for decarbonisation were mentioned less frequently (Figure 5). In particular, external pressure from customers, consumers, and legal regulations were mentioned as the main drivers. Corporate philosophy is relevant in some instances, and the frequency depends also on the professional function of the interview (e.g., strategic vs. operational functions). In regard to support, the new KIG law and the need to do a pilot project, ideally under state support, have been mentioned.

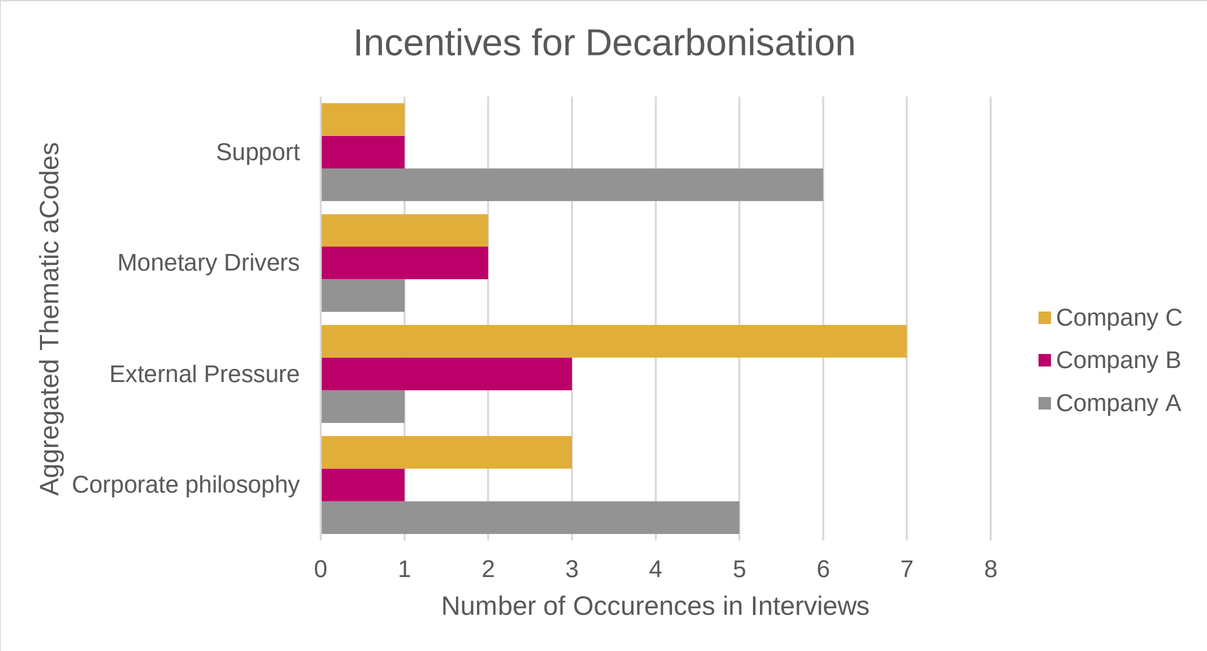

Figure 5 Comparison of aggregated occurrences of codes about Incentives. Results are based on three interviews, coding from two researchers and are aggregated into major categories.

5.3.3 Comparison and discussion

The three interviews have revealed that economic viability, technological challenges and availability of energy and infrastructure are among the major concerns. These findings strengthen the literature's insights into the relevance of technological uncertainty, payback periods, and the need for support (see Section 2.2). In our sample, the companies generally focused on corporate sustainability (see also limitations), which aligns with the finding of a high-target setting.

Generally, the interviews focused on heat pumps and renewable gases. While both the study focus, interview guideline and the selected interviewees may have contributed to this finding, it is nevertheless interesting that options such as solar thermal heat and district heating are not considered despite ongoing research, e.g. in the DECARB SURE project. Furthermore, we would have expected a stronger focus on monetary drivers such as the gas-electricity price ratio (compared to the previous deliverable). However, the lack of current usage of HTHP and experience in these companies may explain the rare mentions.

5.4 Discussion and Limitations

While the semi-structured interviews proved effective in capturing these insights, it is necessary to recognise some limitations inherent to this method. The interview structure and researcher involvement may have introduced biases, potentially shaping the direction of discussions. Moreover, the participation of only three companies—likely those more advanced in their decarbonisation efforts—may have skewed the findings toward more progressive perspectives. This selective participation suggests that these companies are already at the forefront of sustainability initiatives, and their views may not fully represent the broader industry landscape.

Despite these potential biases, the interviews provided a rich understanding of the participants' thinking. They contributed significant inputs for the design of broader surveys and the identification of industry trends. To overcome the limitations of a small, self-selecting sample, we are conducting an additional online survey targeting a larger, more diverse group of companies. The survey will allow us to capture a wider spectrum of perspectives, including those at earlier stages of decarbonisation. Combining qualitative insights from the interviews and quantitative data from the survey will help reduce biases and offer a more comprehensive and balanced view of the industry's decarbonisation efforts.

The additional online survey will broaden the scope of our research, allowing for greater generalizability of the findings and enhancing our understanding of the full range of challenges and opportunities faced by companies in the energy sector. For this, we already have access to a convenience sample, which allows for timely data collection. This approach enables us to gather more generalisable findings and expand this exploratory research. However, convenience sampling (compared to randomised samples) has limitations regarding generalizability, as the sample may not fully represent the broader industry. Such sampling can introduce some bias, as readily available and willing participants may be further in their consideration about decarbonisation. A final evaluation in the addendum will estimate the impact of this bias.

6 Conclusion of the preliminary deliverables and Outlook

While decarbonisation is not a novel concern for the industry—the optimisation of their operations is common practice—technologies such as high-temperature heat pumps (HTHP) and low-carbon fuel still face barriers. Governmental actors and research should thus better understand the underlying reasons, motivations, and needs. Using insights from three interviews with the industry and experts, we uncover major themes of concern among the participating companies, offering valuable insights into their priorities and challenges related to energy transitions and decarbonisation efforts.

In conclusion, the companies actively pursue decarbonisation strategies tailored to their specific operational needs and are committed to reducing carbon footprints through strategic energy management approaches. These efforts include leveraging renewable sources and innovative technologies like heat pumps, biomass, and closed-loop systems. However, for decarbonisation to succeed, key barriers must be overcome, and incentives must be leveraged. The content analysis revealed that our sample of companies is primarily concerned about economic viability, technological challenges, and limited energy infrastructure, which confirms literature insights.

To achieve their long-term decarbonisation goals, the companies need to gain experience with new technologies such as high-temperature heat pumps. We recommend that the SFOE explore the possibility of collaborating in pilot projects to push technology deployment. Furthermore, at least one industry did not perceive Swiss regulatory frameworks in the area of border taxation as ideal for accessing renewable gases and fuels.

While this study and the interviewed companies focused strongly on HTHP, other technologies have not been discussed strongly, e.g. Concentrated Solar Thermal (CST), Hydrogen or the use of district heating grids for industrial purposes, either because they are novel technologies in the industrial context or no infrastructure is available.

Overall, the selected companies share a vision for sustainable operations but are ultimately limited as they need to balance their economic and operational needs. In future work, we first add findings from the broader survey outlined in this deliverable and second explore policy and legal instruments to foster the adoption of decarbonising approaches in the industry sector.

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