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sweet swiss energy research for the energy transition

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Acronyms and abbreviations

AI	Artificial Intelligence
AS	Amtliche Sammlung
BV	Federal Constitution (Bundesverfassung), SR 101
CCS	Carbon Capture and Storage
CO_2-Gesetz	Federal Act on the Reduction of CO_2 Emissions of 23 December 2011 (CO_2-Gesetz), SR 641.71
COP	Coefficient of Performance
CO_2-Verordnung	Ordinance on the Reduction of Carbon Emissions of 30 November 2012 (CO_2-Verordnung), SR 641.711
D	Deliverable
EnG	Energy Act (Energiegesetz), SR 730.0
ESG	Environmental, Social, and Governance
ETS	Emission Trading System
E-CO_2-Verordnung	Ordinance on the Reduction of Carbon Emissions of 30 November 2012 (CO_2-Verordnung), Draft (Vernehmlassungsvorschlag vom 26. Juni 2024)
HTHP	High Temperature Heat Pumps
KlG	Bundesgesetz über die Ziele im Klimaschutz, die Innovation und die Stärkung der Energiesicherheit, SR 814.310
KLG	Klimaverträgliches Lieferketten Gesetz
P&D	Pilot Projects and Demonstration
R&D	Research and Development
SBTi	Science Based Targets initiative
SME	Small and Medium-sized Enterprises
SR	Classified Compilation (Systematische Sammlung)
SuG	Bundesgesetz über Finanzhilfen und Abgeltungen (Subventionsgesetz), SR 616.1
USG	Environmental Protection Act (Umweltschutzgesetz), SR 814.01
WaG	Federal Act on Forest of 4 October 1991 (Waldgesetz), SR 921.0

Disclaimer:

This research report utilised generative AI tools for specific tasks, including outlining, revising, summarising texts and interviews, translations and assisting with grammar and clarity checks. 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

Decarbonizing industrial process heat is essential for Switzerland to meet its climate goals, particularly in the chemical, pharmaceutical, and food industries, which have historically relied on fossil fuels for heat generation. This deliverable report analyzes stakeholder perspectives, policy instruments and mixes, and regulatory frameworks that influence the transition to renewable pathways such as high-temperature heat pumps (HTHPs), alternative gases, and wood. The study highlights economic, technological, and regulatory barriers that hinder the adoption of these solutions and discusses policy measures to accelerate the transition. The report is part of the Basel case study, as the chemical industry in the region plays a central role in industrial transformation, however the survey, interview and legal discussions are not limited to stakeholders or the legislation in that region, providing general insights for Switzerland.

The research is based on a combination of expert interviews and a stakeholder survey targeting industry representatives. The survey provides valuable insights into current energy use, perceived challenges, and policy needs of a sample of the industry. Key barriers identified include high investment costs, long payback periods, regulatory uncertainty, and technical constraints in achieving necessary process temperatures. The findings emphasize that financial incentives, regulatory clarity, and infrastructure development are critical to facilitating decarbonization.

Three policy mixes are proposed to support electrification, alternative gases, and wood-based heating. Electrification policies focus on incentivizing HTHP adoption through investment credits, pilot projects, and R&D funding. Policies for alternative gases emphasize infrastructure expansion, sector-specific mandates, and regulatory adjustments. The wood-based approach considers sustainable allocation to ensure its optimal use in high-temperature applications while maintaining forest sustainability.

From a legal perspective, process heat decarbonization has received little direct attention, as it has historically relied on fossil fuels without significant regulatory challenges. However, recent changes in Swiss climate policies, including the revised CO_2 Act and the Climate and Innovation Act, offer new opportunities to support industry transitions. The legal analysis explores gaps in existing frameworks and potential measures to align industrial energy policies with national decarbonization targets.

Zusammenfassung

Die Dekarbonisierung der industriellen Prozesswärme ist für die Schweiz von entscheidender Bedeutung, um ihre Klimaziele zu erreichen, insbesondere in der chemischen, pharmazeutischen und Lebensmittelindustrie, die in der Vergangenheit auf fossile Brennstoffe zur Wärmeerzeugung angewiesen waren. Dieser Bericht analysiert die Perspektiven der Interessengruppen, die politischen Instrumente und den Mix sowie die rechtlichen Rahmenbedingungen, die den Übergang zu erneuerbaren Energien wie Hochtemperaturwärmepumpen (HTHP), alternativen Gasen und Holz beeinflussen. Die Studie hebt wirtschaftliche, technische und regulatorische Hindernisse hervor, die die Einführung dieser Lösungen behindern, und erörtert politische Massnahmen zur Beschleunigung dieser Umstellung. Der Bericht ist Teil der Basler Fallstudie, da die chemische Industrie in der Region eine zentrale Rolle bei der industriellen Transformation spielt. Die Umfrage, die Interviews und die juristischen Diskussionen sind jedoch nicht auf die Akteure oder die Gesetzgebung in dieser Region beschränkt, sondern bieten allgemeine Einblicke für die Schweiz.

Die Untersuchung basiert auf einer Kombination aus Experteninterviews und einer Umfrage unter Vertretern der Industrie. Die Umfrage liefert wertvolle Einblicke in die aktuelle Energienutzung, die wahrgenommenen Herausforderungen und die politischen Bedürfnisse einer Stichprobe der Branche. Zu den wichtigsten Hindernissen, die ermittelt wurden, gehören hohe Investitionskosten, lange Amortisationszeiten, regulatorische Unsicherheiten und technische Beschränkungen beim Erreichen der erforderlichen Prozesstemperaturen. Die Ergebnisse unterstreichen, dass finanzielle Anreize, klare Vorschriften und die Entwicklung der Infrastruktur entscheidend sind, um die Dekarbonisierung zu erleichtern.

Zur Förderung der Elektrifizierung, der alternativen Gase und der Holzfeuerung werden drei Politikmixe vorgeschlagen. Die Policy der Elektrifizierung konzentriert sich auf Anreize für die Einführung von HTHP durch Investitionskredite, Pilotprojekte und F&E-Finanzierung. Die Massnahmen für alternative Gase konzentrieren sich auf den Ausbau der Infrastruktur, sektorspezifische Mandate und regulatorische Anpassungen. Der holzbasierte Ansatz berücksichtigt die nachhaltige Nutzung, um eine optimale Verwendung in Hochtemperaturanwendungen zu gewährleisten und gleichzeitig die Nachhaltigkeit der Wälder zu erhalten.

Aus rechtlicher Sicht wurde der Dekarbonisierung von Prozesswärme bisher wenig Aufmerksamkeit geschenkt, da sie in der Vergangenheit auf fossilen Brennstoffen beruhte und keine nennenswerten regulatorischen Herausforderungen mit sich brachte. Die jüngsten Änderungen in der Schweizer Klimapolitik, einschliesslich des revidierten CO_2-Gesetzes und des Klima- und Innovationsgesetzes, bieten jedoch neue Möglichkeiten zur Unterstützung der Umstellung der Industrie. Die rechtliche Analyse untersucht Lücken in den bestehenden Rahmenbedingungen und mögliche Massnahmen, um die industrielle Energiepolitik mit den nationalen Dekarbonisierungszielen in Einklang zu bringen.

Résumé

La décarbonisation de la chaleur industrielle est essentielle pour que la Suisse atteigne ses objectifs climatiques, en particulier dans les industries chimiques, pharmaceutiques et alimentaires, qui dépendent historiquement des combustibles fossiles pour la production de chaleur. Ce rapport analyse les perspectives des parties prenantes, les instruments et les combinaisons de politiques, ainsi que les cadres réglementaires qui influencent la transition vers des voies renouvelables telles que les pompes à chaleur à haute température (HTHP), les gaz alternatifs et le bois. L'étude met en évidence les obstacles économiques, technologiques et réglementaires qui entravent l'adoption de ces solutions et examine les mesures politiques qui permettraient d'accélérer la transition. Le rapport fait partie de l'étude de cas de Bâle, car l'industrie chimique de la région joue un rôle central dans la transformation industrielle. Cependant, l'enquête, les entretiens et les discussions juridiques ne se limitent pas aux parties prenantes ou à la législation de cette région, et fournissent des informations générales pour la Suisse.

La recherche est basée sur une combinaison d'entretiens avec des experts et d'une enquête auprès des parties prenantes ciblant les représentants de l'industrie. L'enquête fournit des informations précieuses sur l'utilisation actuelle de l'énergie, les défis perçus et les besoins politiques d'un échantillon de l'industrie. Les principaux obstacles identifiés sont les coûts d'investissement élevés, les longues périodes d'amortissement, l'incertitude réglementaire et les contraintes techniques liées à l'obtention des températures de traitement nécessaires. Les résultats soulignent que les incitations financières, la clarté de la réglementation et le développement de l'infrastructure sont essentiels pour faciliter la décarbonisation.

Trois combinaisons de politiques sont proposées pour soutenir l'électrification, les gaz alternatifs et le chauffage à base de bois. Les politiques d'électrification se concentrent sur l'incitation à l'adoption des HTHP par le biais de crédits d'investissement, de projets pilotes et de financement de la recherche et du développement. Les politiques relatives aux gaz de substitution mettent l'accent sur l'expansion des infrastructures, les mandats sectoriels et les ajustements réglementaires. L'approche fondée sur le bois tient compte de l'allocation durable pour garantir son utilisation optimale dans les applications à haute température tout en préservant la durabilité des forêts.

D'un point de vue juridique, la décarbonisation de la chaleur industrielle a reçu peu d'attention directe, car elle s'est toujours appuyée sur les combustibles fossiles sans poser de problèmes réglementaires importants. Cependant, les récents changements dans les politiques climatiques suisses, y compris la loi révisée sur le CO_2 et la loi sur le climat et l'innovation, offrent de nouvelles opportunités pour soutenir les transitions de l'industrie. L'analyse juridique explore les lacunes des cadres existants et les mesures potentielles pour aligner les politiques énergétiques industrielles sur les objectifs nationaux de décarbonisation.

Sintesi

La decarbonizzazione del calore dei processi industriali è essenziale per la Svizzera per raggiungere i suoi obiettivi climatici, in particolare nelle industrie chimiche, farmaceutiche e alimentari, che storicamente si sono affidate ai combustibili fossili per la generazione di calore. Questo rapporto analizza le prospettive degli stakeholder, gli strumenti e i mix di politiche e i quadri normativi che influenzano la transizione verso percorsi rinnovabili come le pompe di calore ad alta temperatura (HTHP), i gas alternativi e il legno. Lo studio evidenzia le barriere economiche, tecnologiche e normative che ostacolano l'adozione di queste soluzioni e discute le misure politiche per accelerare la transizione. Il rapporto fa parte del caso di studio di Basilea, in quanto l'industria chimica della regione svolge un ruolo centrale nella trasformazione industriale; tuttavia, l'indagine, le interviste e le discussioni legali non si limitano agli stakeholder o alla legislazione di quella regione, fornendo spunti generali per la Svizzera.

La ricerca si basa su una combinazione di interviste a esperti e un'indagine sugli stakeholder rivolta ai rappresentanti del settore. L'indagine fornisce preziose indicazioni sull'uso attuale dell'energia, sulle sfide percepite e sulle esigenze politiche di un campione del settore. Tra gli ostacoli principali individuati vi sono gli elevati costi di investimento, i lunghi periodi di ammortamento, l'incertezza normativa e i vincoli tecnici nel raggiungimento delle necessarie temperature di processo. I risultati sottolineano che gli incentivi finanziari, la chiarezza normativa e lo sviluppo delle infrastrutture sono fondamentali per facilitare la decarbonizzazione.

Sono stati proposti tre mix di politiche per sostenere l'elettrificazione, i gas alternativi e il riscaldamento a legna. Le politiche per l'elettrificazione si concentrano sull'incentivazione dell'adozione di HTHP attraverso crediti d'investimento, progetti pilota e finanziamenti per la ricerca e lo sviluppo. Le politiche per i gas alternativi sottolineano l'espansione delle infrastrutture, i mandati specifici per il settore e gli adeguamenti normativi. L'approccio basato sul legno considera l'allocazione sostenibile per garantire l'uso ottimale in applicazioni ad alta temperatura, mantenendo la sostenibilità delle foreste.

Da un punto di vista legale, la decarbonizzazione del calore di processo ha ricevuto poca attenzione diretta, in quanto storicamente si è basata su combustibili fossili senza significative sfide normative. Tuttavia, i recenti cambiamenti nelle politiche climatiche svizzere, tra cui la revisione della legge sul CO_2 e la legge sul clima e l'innovazione, offrono nuove opportunità per sostenere le transizioni industriali. L'analisi legale esplora le lacune dei quadri normativi esistenti e le potenziali misure per allineare le politiche energetiche industriali agli obiettivi nazionali di decarbonizzazione.

1 Introduction

Decarbonizing the industrial sector is essential for Switzerland to meet its climate goals, given the sector's significant contribution to overall emissions. Previous research has demonstrated the technical feasibility of various decarbonization options (Jakob, Melliger, Bagemihl, & Talary, 2023). This deliverable explores the stakeholder views, and how legal and regulatory mechanisms can accelerate the decarbonization of process heat in the chemical, pharmaceutical, and food industries.

Process heat production—typically within the 40°C to 200°C range (Arpagaus, 2019) —remains heavily reliant on fossil fuels. However, the transition to renewable sources is feasible, with options such as high-temperature heat pumps (HTHPs), renewable gases, and wood offering potential alternatives. Despite progress in decarbonization, these technologies continue to face significant barriers (Melliger, Talary, Jakob, & Berti, 2024). Challenges include technological constraints related to immaturity and limitations in achieving required temperatures, economic obstacles such as high investment costs and dependency on volatile energy prices, and resource availability issues that affect the scalability of alternative gases and wood. Moreover, industrial stakeholders frequently experience information gaps and lack experience in handling these technologies, leading to calls for pilot programs to support adoption.

Addressing these challenges requires targeted policy interventions. Switzerland has introduced new decarbonization policies in recent years, and global initiatives such as the EU Taxonomy, ESG metrics, and Science-Based Targets (SBTi) have played a role in shaping corporate sustainability efforts. However, regulatory gaps may persist, highlighting the need for a stakeholder-driven review and a legal analysis. Overall, process heat decarbonisation remains a relatively novel topic from a legal perspective, raising concerns about the feasibility and practical implementation of these options within the current regulatory framework. From a legal perspective, little attention has been paid to process heat because it was produced by burning gas or oil on site, which rarely raised legal questions.

To support effective policymaking, we conduct a stakeholder survey, assessing industry perspectives on decarbonization barriers, as well as a comprehensive legal gap analysis to evaluate the existing regulatory landscape and identify opportunities for policy development. The study is guided by the central research question: *What are the key barriers to the decarbonization of industrial process heat in the chemical, pharmaceutical, and food industries, and how can legal and policy frameworks facilitate this transition and meet the industry's needs?*

Building on our previous work, which included preliminary company interviews and a proposed survey design, this study expands the analysis through survey result analysis. We propose three policy mixes for the key decarbonization pathways of electrification, alternative gases, and wood. The recommendations aim to balance climate policy objectives with economic, operational, and legal realities, ensuring that proposed measures are both ambitious and implementable. Given the prominence of the chemical industry in the Basel region, this study also connects to the overarching case study on regional industrial transformation while offering insights applicable to companies with similar heat and temperature requirements. Ultimately, this work contributes to fostering a sustainable and adaptable transformation of industrial process heat systems.

2 Methodology

The methodology section outlines the research approach used to assess the barriers and policy solutions for industrial process heat decarbonization. Section 2.1 defines the scope and system boundaries, focusing on the decarbonization needs of the chemical, pharmaceutical, and food industries. Section 2.2 presents the research design, including expert interviews and stakeholder surveys, which provide insights into industry perspectives on electrification through high-temperature heat pumps (HTHPs), the use of alternative gases such as hydrogen and biomethane, and wood-based heating. Section 2.3 details the survey methodology, including sampling strategies and analysis techniques, while Section 2.4 introduces the method to derive the policy-mix proposal derived from stakeholder input. Finally, Section 2.5 presents the method of the legal analysis, evaluating existing regulatory frameworks and identifying gaps that impact the feasibility and implementation of decarbonization policies.

2.1 Scope: options and system boundaries

The scope of this deliverable builds upon the scope of deliverable D15.2 (Melliger, Talary, Jakob, & Berti, 2024). This means, we analyse the needs of the chemical, pharma and food industries in Switzerland in the process of decarbonization. With this, an implicit technological focus lies on the processes prevalent in these industries which require heat temperatures between 40°C and 200°C. In this range, three main decarbonization options exist:

- **Electrification**: This entails foremost HTHP but also includes power to gas technologies or direct heating.

- **Alternative gases**: This entails biogases, synthetic gases, biomethane and hydrogen. One important commonality is their need for specialised infrastructures such as tanks or pipelines.

- **Wood:** This includes both fresh and recycled wood used for energy purposes.

For these three options, we assess the stakeholder needs, potentials and existing policies and the legal grounds to foster / accelerate the energy transition and resource protection. The survey (see Section 3.3) provides evidence that these three options are relevant for the decarbonization in the industry (depending on specific circumstances). While other energy sources such as solar heat have a certain relevance in the ongoing decarbonization (Giampietro et al., 2024; Tasmin, Farjana, Hossain, Golder, & Mahmud, 2022), we classify them as a heat source. In industry, heat from solar installations is mostly suitable in combination with HTHPs to increase the process heat level. Hence, we do not further consider or analyse needs and policies related to such technologies[1].

Carbon prices and the emission trading system are relevant aspects of transition towards fossil-free technologies. However, we do not deeply investigate such markets and prices in our deliverable as it is mainly a market mechanism. Instead, we consider the carbon price as a factor which might affect the implementation of policies in the future, but we do not propose or analyse related policies to intervene in these markets.

2.2 Interviews and research design

2.2.1 Interviews

For the analysis of the stakeholder perspective, we first draw both from a previous deliverable (deliverable D15.2., Melliger et al., 2024)) and expert interviews. We performed five semi-structured interviews with experts from consulting companies and with peers. They provided valuable insights into current trends. In addition, we summarize findings from the related to illustrate the background knowledge. Second, we

[1] With the new CO2-law / KIG polices already exist

2.2.2 Survey sampling

Survey results and findings are based on responses from the chemical, pharma and food industries, providing insights into current barriers, challenges, and the relevance of policies and instruments. It employed a convenience sampling approach, drawing from participants provided by an industry (umbrella-)association as well as independent outreach. A detailed overview of the sampling process is available in Deliverable 15.2.

Data collection took place between late 2024 and early 2025. To maximize participation, we sent two reminders over a two-month period and, in some cases, contacted representatives by phone. Despite these efforts, the response rate remained low, with only 13 fully completed responses, 11 of which reported process heat demand. One participant who partially completed the survey was included in the analysis, as well. Given the low response rate, their responses were deemed valuable and retained (included in sections 3.3.1 and 3.3.2.)

Given the limited number of companies in the specific sectors (estimated at 200–350 companies in Switzerland)[2], the response rate remains informative. The limited participation may be due to factors such as survey fatigue and time constraints of decision-makers (see Section 6.4). While the sample may not be fully representative, the findings provide valuable insights into industry needs and barriers. These results offer a foundation for policy development, which should be further strengthened through collaborative processes and broader stakeholder engagement.

2.2.3 Survey design and analysis

Our survey was designed following the methodological approach outlined in D15.2 (Melliger et al., 2024). The survey focused on questions relevant to the policy and legal dimensions of our deliverable, specifically addressing the suitability of decarbonization options, policy needs and general barriers. The evaluation of the survey results is presented both in Section 3.3 and in the appendix (serving also as an amendment to D15.2).

The survey examines barriers, challenges and needs and in particular the role of framework conditions, policy instruments & guidelines and key stakeholders. Given the policy focus of this deliverable, special emphasis was placed on the role of various instruments and policies such as the Climate and Innovation Act (KIG), investment contributions, CO_2-regulations, electricity discounts, pilot projects, and research and development (R&D) support. Questions about these barriers, challenges and needs were included as closed-ended questions, for which we utilised a Likert-type scale to assess the perceived relevance. Unless indicated otherwise, responses were categorised on a four-point scale, with 1 representing the least likely and 4 representing the most likely category. We summarized the results in overviews tables and calculated median values based on response distributions. Non-applicable responses were excluded from quantitative analysis and considered qualitatively.

We initially hypothesized that response distributions would differ significantly between the food industry and the chemical & pharmaceutical sectors. To test this hypothesis, we conducted a Chi-Square test to compare responses from the two groups. The results indicated no statistically significant differences ($p > 0.05$) in most question types, suggesting similar response patterns across industries with process heat demand. Consequently, result tables represent responses from both sectors.

Alongside the close-ended questions, we included open-ended questions to learn about specific circumstances. We summarised the content of those questions with the help of AI-tools[3]. Furthermore, to ensure accessibility, the questionnaire was provided in German, English, and French, with each version reviewed by native or fluent speakers for accuracy. While minor variations in interpretation may have

[2] The Survey was sent over the mailing list of the industry association. We do not have the exact numbers the survey was sent to, but a rough estimate of the number of members is 200-300. With this, the total statistical population is estimated to be between 200-350 (based on the fact that not all 200-300 members qualify for our scope).

[3] Notably ChatGPT.

occurred, the predominance of responses in German contributes to strong overall data consistency. Finally, the survey was conducted primarily through an online questionnaire, chosen for its efficiency in reaching a diverse audience.

2.2.4 Policy-mix proposal

We propose policy mixes based on a solid foundation of expert and stakeholder knowledge, ensuring a well-rounded and contextually relevant approach. By analysing the challenges identified through the survey and previous expert interviews, we were able to pinpoint key issues and policy gaps that required targeted solutions. The resulting policy mixes aim balancing feasibility, effectiveness, and stakeholder priorities. Market-based policies, such as the Swiss ETS, are not considered for the proposals. While they have relevance as highlighted in the interviews, we focus on regulatory, informational and direct support instruments rather than price- and tax-based ones (see section abouts scopes above for a detailed description).

While our approach is grounded in expert and stakeholder input, including insights from our peers, it does not include a formal policy analysis in the sense of an economic or impact assessment. Instead, the focus remains on developing a coherent and well-informed set of policy measures that address the identified challenges. To ensure practical relevance, a legal analysis was conducted to determine whether the proposed policies already exist or are realistic from a legal perspective, ensuring their feasibility within the current regulatory framework (see next subsection).

2.2.5 Legal analysis

For the analysis of the legal perspective, we rely on desk research and analysis (i.e. scientific literature review and evaluation of the legal framework). Building on the policy instrument overview in Part 4 we analyse the legal landscape regarding the suggested policy instruments that are derived from the survey-results. Focus is laid on the distribution of competencies between federal legislator and the Cantons and the basic legal provision directing the suggested instruments.

3 Stakeholder perspective: Analysis of survey and interviews

The stakeholder perspective section explores relevant information for various sources to paint a complete picture of the policy needs and barriers to the decarbonization in Switzerland. Section 3.1 aggregates findings of a previous deliverable (Melliger et al. 2024), in which stakeholders of the chemical, pharmaceutical and the food industry were interviewed and the responses analysed using content analysis. In this deliverable, we presents original interviews with experts and peers related to the overall topic of process heat decarbonization in Section 3.2, and a comprehensive survey analysis with industry stakeholder (i.e. industry decision-makers, operational and strategic personnel) in Section 3.3 .

3.1 Stakeholder involvement

3.1.1 Interviews and previous results

In Melliger et al. (2024), we explored the literature and context for the decarbonization of industrial process heat. In Switzerland, a robust policy framework supports decarbonization through various instruments already (namely target agreements, energy analyses, decarbonization roadmaps with mandatory participation for large energy consumers, and the Emission Trading System). However, adoption challenges persist, including technological immaturity and long payback periods. Studies highlight the sector's heterogeneity, with some industries requiring tailored solutions for specific processes and infrastructure challenges (such as the upscale electricity supply).

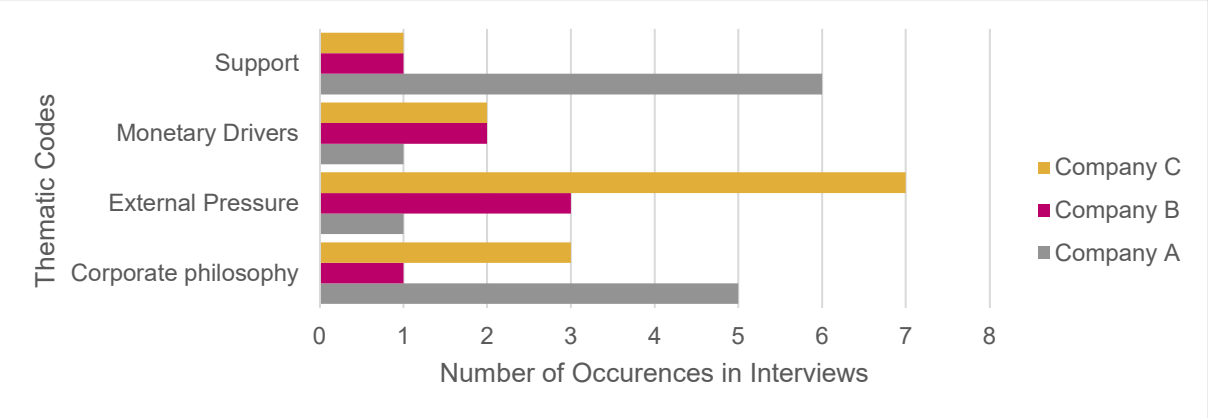

Figure 1 Comparison of aggregated occurrences of codes about incentives. Results are based on three interviews, coding from two researchers and are aggregated into major categories. Source: Melliger et al., 2024)

The three interviews in Melliger et al. (2024) raised the following concerns, which are relevant in the context of the current deliverable:

1. **Economic viability**: Companies face challenges in balancing decarbonization goals with economic needs, particularly given volatile energy prices. Fixed personnel and maintenance costs in energy production limit cost flexibility. In addition, while efficiency improvements are generally beneficial, they may unexpectedly result in reduced revenue for internal energy suppliers.[4]

2. **Support and pilot programs**: Some companies highlight the need for government funding and policy mechanisms, such as those provided under the Climate and Innovation Act (KIG), to help finance innovative decarbonization projects. They have shown interest to cooperate with the federal office of energy (SFOE) to set up pilot projects (this also applies to the sample in the survey). Overall, a content analysis showed that financial support does not seems to be the

[4] This also applies to external energy suppliers, which are a relevant stakeholder in the decarbonization effort.

central need of the interviewed companies, but cannot be neglected, and is also relevant to adjust the monetary drivers (Figure 1).

3. **Perception of specific policy barriers**: In the view of one stakeholder, clearance rules disadvantage the import of biogas. Even though these regulations have been altered in the meantime, biogas is still not fully exempt from the CO2-tax, providing barriers.

4. **Regulatory uncertainty**: Long-term planning is complicated by unclear policies surrounding CO_2 emissions reduction and renewable energy targets, making it difficult for companies to commit to decarbonization investments confidently.

3.2 Summary of expert interviews

The expert interviews revealed both common and industry-specific challenges in decarbonization efforts. While the chemical and pharmaceutical industry faces significant hurdles in scaling technologies and aligning regulations, the food industry, particularly SMEs, struggles with financial constraints, infrastructure limitations, and operational disruptions. The table below provides a structured comparison of key barriers, policy needs, and regulatory effectiveness in both sectors.

Table 1 Comparative summary of expert interviews. See Appendix 8.1 for the expanded interview summaries.

Category	Chemical & Pharmaceutical Industry (Expert 1)	Food Industry (Expert 2)
Economic Barriers	The high cost of alternative technologies, such as hydrogen and biogas, makes adoption financially challenging. Market distortions caused by subsidies can favour niche solutions that may not scale effectively.	Retrofitting industrial systems for renewable energy (e.g., switching from steam to heat pumps) is costly and disruptive. SMEs often lack the financial resources to absorb these costs and handle production interruptions.
Technical Challenges	Many decarbonization technologies, such as high-temperature heat pumps, are not yet ready for large-scale implementation. Some industrial processes, like drying and neutralization, require precise temperature control, making the transition more complex. Existing infrastructure is often incompatible with new low-carbon technologies.	Transitioning to renewable energy requires site-specific solutions and additional space for infrastructure, such as energy storage. Many facilities, particularly those in heritage buildings, face spatial constraints. Renewable systems are also less effective for peak energy demands.
Regulatory & Market Barriers	Unclear certification systems for renewable energy imports create uncertainty. Environmental concerns, such as methane emissions from biogas production, further complicate decision-making.	Fluctuating energy prices make it difficult for companies to assess the long-term cost-effectiveness of new technologies. While recent regulatory updates (e.g., 2024 CO_2-law) provide more clarity, uncertainty about future policies still slows investment.
Knowledge Gaps & Risk Aversion	Many decision-makers lack expertise in thermodynamics and process optimization, leading to misaligned expectations about decarbonization technologies. Companies are hesitant to adopt new technologies due to	SMEs often lack in-house expertise on energy systems and are cautious about adopting new technologies due to past failures. Limited staffing and a focus on daily operations make long-term strategic planning difficult.

	concerns about operational risks and reliability.	
Financial Support Needs	Policies should prioritize large-scale subsidies, increased R&D funding, and tax incentives to reduce cost barriers and accelerate technology deployment. Internationally harmonized standards would help facilitate cross-border trade in renewable energy.	SMEs require targeted financial support, such as low-interest loans, green financing options, and grants for pilot projects. These measures would help reduce the high initial investment costs and alleviate concerns about financial risk.
Advisory & Knowledge-Sharing Needs	Expanding training programs for engineers and decision-makers would improve understanding of decarbonization technologies. Pilot projects and public-private partnerships could help demonstrate feasibility and mitigate risks.	Providing SMEs with structured decarbonization roadmaps and centralized heat supply strategies would support decision-making. Industry partnerships and knowledge-sharing initiatives could improve awareness and confidence in new technologies.
Infrastructure Development Needs	Expanding infrastructure for hydrogen transport, seasonal energy storage, and resilient supply chains is crucial to support large-scale industrial decarbonization.	Strengthening the energy grid and improving infrastructure for renewable energy integration would make the transition smoother, especially for SMEs with space constraints.
Market Pressures & Accountability	Policies such as Scope 3 emissions regulations (SBTi) create pressure along the supply chain, encouraging suppliers to decarbonize.	Large corporations increasingly require their suppliers to adopt sustainable practices, pushing SMEs to align with these demands. Simplified regulatory processes would make it easier for SMEs to comply.
Effectiveness of Current Political Instruments	While net-zero roadmaps, ESG standards, and emissions trading systems (ETS) provide some structure, they are not always effective for large industrial players already driven by supply chain requirements. Exemptions for fossil fuel use can slow the transition to renewable energy.	SMEs often struggle with the complexity of accessing financial incentives and support programs. Simplifying the application process and clearly defining funding eligibility would increase participation.

For a more detailed overview of each expert's insights, refer to the Appendix 8.1 for the full interview summaries.

3.3 Survey results

3.3.1 Current and potential energy carriers

This section presents the survey findings for key processes and their current energy sources (Figure 2), and potential options (Figure 3) for decarbonizing these processes. In addition, the transition progress illustrates companies' status as of 2024 (Figure 4 and Figure 5). The responses provide insights into industry preferences, constraints, and feasibility considerations for transitioning to lower-carbon alternatives. Overall, we observe that natural gas is still the most used energy carrier in our sample, but that considerations to transition are advanced or partly completed. While about one quarter of the industries would still be dependent on alternative energy sources, electrification through direct heating or high temperature heat pumps will dominate. District heating only plays a minor role, informing product development of local heat and energy suppliers. We also enquired about the possibility of alternative energy options. Due to a small number of responses, no general insights can be drawn despite the notion that the choice of fuel options may be very context-specific (Table 12 in Appendix).

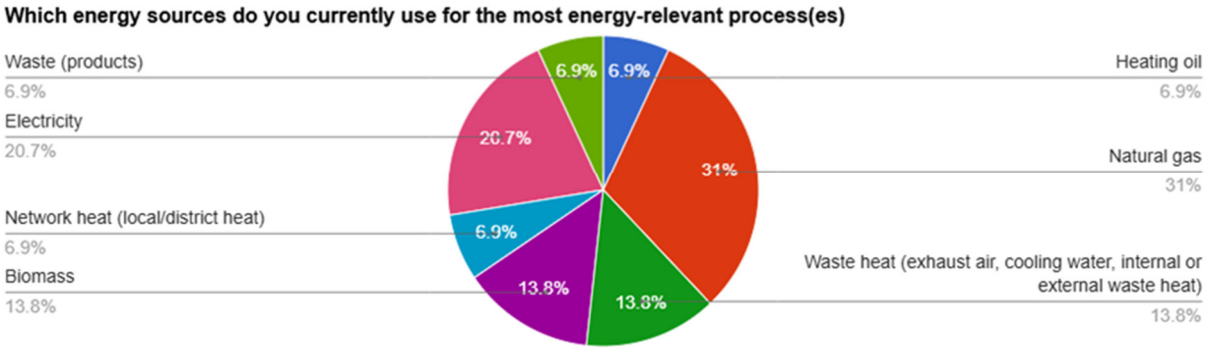

Figure 2: Survey results for the question about current energy carriers. Shares indicate the number of mentions based on total count of 29 (multiple answers per participant were possible).

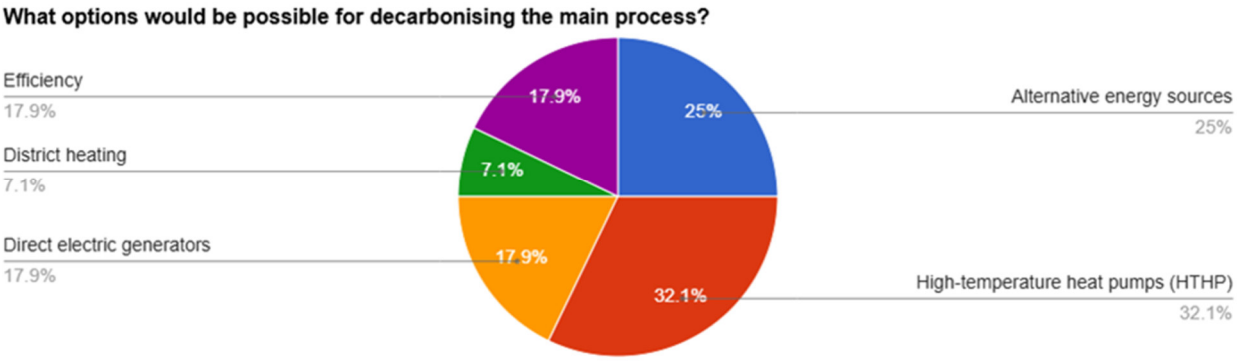

Figure 3: Survey results for the question about potential options. Shares indicate the number of mentions based on total count of 28 (multiple answers per participant were possible).

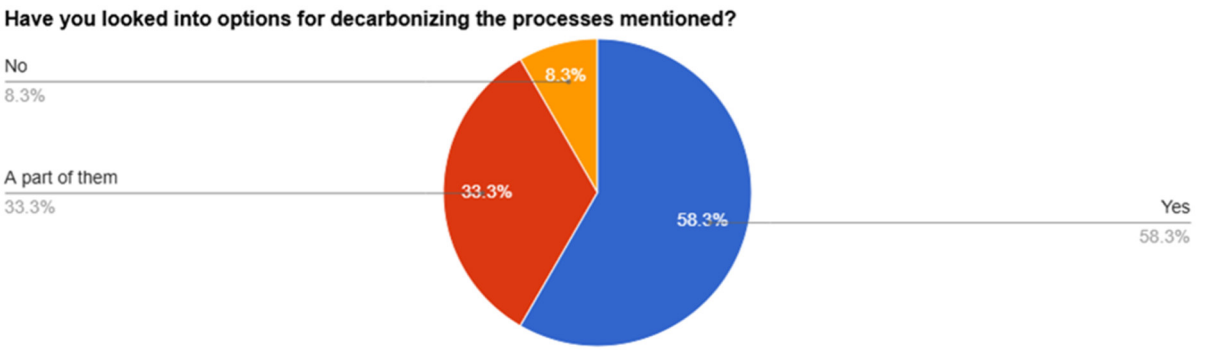

Figure 4: Survey results for the first question about the transition process. Shares indicate the number of mentions based on total count of 12.

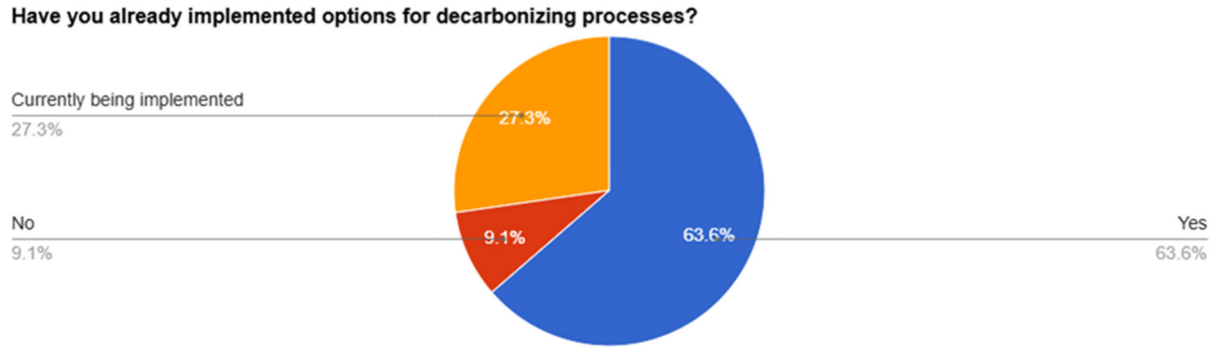

Figure 5: Survey results for the second question about the transition process'. Shares indicate the number of mentions based on total count of 12.

3.3.2 Barriers and challenges for adoption

Survey results reveal common views on the technical, economic, legal, and regulatory barriers to adopting **alternative energy and gases**. For industries where these alternatives are relevant, multiple barriers exist (Table 2). However, the most significant challenges are economic efficiency and the availability of infrastructure, meeting our expectations. Conversion efforts are highlighted by some of the respondents but may be very specific.

Table 2: Results for the question: 'What obstacles have you encountered when using renewable energy sources to date?' The 'Ø Median' columns represent the weighted average of responses on a scale of 1 to 4 (1 = 'does not apply', etc.). All other numbers indicate the number of participants who selected each response.

Question: What obstacles have you encountered when using renewable energy sources to date? (sample size = 12)	Ø Median	Does not apply	Rather not true	More likely	Absolutely true	Not relevant / n/a.
Achievable temperature level	2.11	5	0	2	2	3
Flexibility of energy sources	2.38	2	2	3	1	4
Economic efficiency and costs	3.8	0	0	2	8	2
Availability of infrastructure	3	1	1	4	3	3
Security of energy supply	2.38	2	2	3	1	4
Technological readiness	3	0	2	3	2	5
Regulatory barriers	1.78	3	5	1	0	3
Eligibility of certificates	1.5	3	3	0	0	6
Conversion effort	2.7	1	3	4	2	2
Space conditions / requirements	2.4	1	5	3	1	2

For the adoption of **high-temperature heat pumps,** other barriers are more relevant (Table 3). The most important barriers are economic efficiency and the achievable temperature levels, which highlights the need for further technological advancements, and the need for policy support (both targeting costs and technological learning, see Section 4), or a switch to alternative gases or wood.

Table 3: Results for the question: “What obstacles have existed so far to using high-temperature heat pumps?”. The 'Ø Median' columns represent the weighted average of responses on a scale of 1 to 4 (1 = 'does not apply', etc.). All other numbers indicate the number of participants who selected each response.

Question: What obstacles have existed so far for using high-temperature heat pumps? (sample size = 12)	Ø Median	Does not apply	Rather not true	More likely	Absolutely true	Not relevant / n/a.
No usable heat source available	1.9	5	2	2	1	2
Achievable temperature level	3.2	1	1	3	5	2
No suitable solutions available	2.89	1	2	3	3	3
Complexity of the conversion / retrofitting	2.91	1	2	5	3	1
Space conditions / requirements	2.45	1	6	2	2	1
No experience with integration into existing processes	2.33	1	5	2	1	3
Economic efficiency / payback periods	3.55	0	1	3	7	1
Lack of political framework	2.25	3	2	1	2	4
Lack of funding instruments	2.56	2	2	3	2	3

In open-ended questions, respondents highlighted additional challenges impacting the transition to alternative energy sources (see also Appendix 8.2.1). Technological limitations make achieving high process temperatures (above 200°C) difficult, with limited maturity of solutions for temperature above 170°C. Process knowledge gaps and insufficient waste heat streams further hinder energy recovery efforts. Economic constraints, including high investment costs, low efficiency (COP), and long amortization periods, make certain decarbonization solutions financially unviable, with investment willingness often emerging only after signing SBTi targets. Infrastructure challenges also play a significant role, as transitioning from reliable steam boilers is both complex and expensive. Space constraints, extensive piping requirements, and incompatibility with existing process equipment (designed for 160°C steam) further complicate implementations. Finally, regulatory barriers, particularly related to pharma-registered processes, add another layer of complexity, limiting the feasibility of alternative energy solutions in specific industries.

3.3.3 Perception of relevance of legal and policy instruments

To develop a policy mix proposal for industrial heat decarbonization (see next section), we surveyed companies on the **relevance of guidelines, stakeholders, initiatives, and policies**. Regarding guidelines (Table 4), *CO_2 exemptions through target agreements* and *reduction pathways* play a crucial role. In contrast, import tariffs and the EU ETS are not significant for most companies in our sample. Similarly, for initiatives (Table 5), SBTi, ESG, and customer specifications are highly relevant, whereas the EU taxonomy has little impact—at least in our sample

Table 4: Results for the question: "The following guidelines play a crucial role in the decarbonization of my company.". The 'Ø Median' columns represent the weighted average of responses on a scale of 1 to 4 (1 = 'does not apply', etc.). All other numbers indicate the number of participants who selected each response.

Question: The following guidelines play a crucial role in the decarbonization of my company. (sample size = 11)	Ø Median	Does not apply	Rather not true	More likely	Absolutely true
CO2 exemption through target agreement	2.8	3	0	4	4
Reduction pathway	3.2	1	0	6	4
EU Emissions Trading System	2.3	5	2	0	4
Swiss emissions trading system	2.8	2	3	1	5
Import tariff	1.4	9	1	0	1

Table 5: Results for the question: “The following stakeholders and initiatives play a crucial role in the decarbonization of my company.”. The 'Ø Median' columns represent the weighted average of responses on a scale of 1 to 4 (1 = 'does not apply', etc.). All other numbers indicate the number of participants who selected each response.

Question: The following stakeholders and initiatives play a crucial role in the decarbonization of my company. (sample size = 11)	Ø Median	Does not apply	Rather not true	More likely	Absolutely true
EU Taxonomy	1.5	7	3	1	0
Science Based Targets Initiative (SBTi)	3.1	2	1	2	6
Environmental, Social Governance (ESG)	2.8	2	3	1	5
Customer specifications	2.9	0	2	8	1
Consumer expectations	2.5	2	3	5	1

Asking about the relevance of **policy instruments** to decarbonise the business (Table 6), we derive no unanimous trends. While there is a slight tendency for companies to favour industry measures from the *CO_2 Regulation and the Climate and Innovation Act,* responses in this sample size are fairly evenly distributed around moderate relevance (rather not true & more likely). This suggests that while state policies play a role in driving decarbonization, they are not the sole determining factor

Table 6: Results for the question: “The following instruments play a crucial role in decarbonising my business.”. The 'Ø Median' columns represent the weighted average of responses on a scale of 1 to 4 (1 = 'does not apply', etc.). All other numbers indicate the number of participants who selected each response.

Question: The following instruments play a crucial role in decarbonising my business. Sample size =11	Ø Median	Does not apply	Rather not true	More likely	Absolutely true
Climate and Innovation Act	2.9	1	2	5	3
Investment contributions for retrofits / transition	2.6	1	5	3	2
Measures for industry from the CO2 regulation	2.7	1	4	3	3
Electricity discounts	2.1	3	5	2	1
Promotion of own pilot projects	2.4	3	2	5	1
Promotion of R&D	2.3	2	4	5	0

In open-ended questions, Respondents identified several additional drivers influencing decarbonization efforts, including economic factors, policy frameworks, external pressures, and technological considerations (see also Appendix 8.2.1). Lower electricity prices were highlighted as crucial for making heat pumps economically viable, while uncertainties around hydrogen availability, pricing, and CO_2 taxes remain key concerns. The European Green Deal and large customers/industry associations play a significant role in shaping decarbonization strategies, but resistance to passing additional costs onto products poses a challenge. Some respondents emphasized the importance of aligning with network surcharge refunds and decarbonization targets, highlighting that projects like carbon capture and storage (CCS) and electric boilers may seem inefficient but contribute significantly to CO_2 reduction. Lastly, while initiatives such as the Climate-Compatible Supply Chains Law (KLG - Klimaverträgliches Lieferketten-Gesetz) are seen as positive, achieving a Net Zero roadmap remains difficult for complex industries due to technological limitations and Scope 3 emission challenges.

The next section examines how a comprehensive policy mix—addressing both supply- and demand-side measures—can help overcome these challenges, ensuring an effective and economically viable transition for industrial heat decarbonization (Section 4).

4 Overview of potential policy mixes

State policy mixes play a crucial role in shaping decarbonization pathways, providing the framework conditions and incentives needed to accelerate the transition. While our survey results indicate that other factors—such as market dynamics, technological advancements, and corporate sustainability strategies—also drive decarbonization, well-designed policies can effectively support and amplify these efforts. This chapter explores three policy mixes, each combining various instruments to facilitate process heat decarbonization through electrification, alternative gases, and energy wood, along with their intended impact.

Building on expert knowledge (see Section 2.2.4), we propose complementary policy mixes that enhance existing instruments such as reduction pathways and target agreements. These proposals address key challenges identified through our survey and expert interviews. A legal analysis follows to assess the feasibility of the proposed policy mixes within the current regulatory framework (see next subsection).

4.1 Electrification

Electrification through HTHPs holds the highest potential for decarbonizing industrial heat production among other power-to-heat options. However, challenges related to upper temperature limits and limited industrial experience necessitate policies that facilitate market entry and technology development (Jakob, Melliger, Bagemihl, & Talary, 2023). A robust policy mix must address both the supply and demand sides to stimulate learning curves and foster technology adoption.

Proposed policy mix

Supply-side measures

- **Subsidy contracts for suppliers**: Financial incentives should be linked to development goals, ensuring that manufacturers of HTHPs focus on reducing costs and advancing technological capabilities. Regular evaluations should assess the continued necessity of these subsidies and their impact on market growth.

- **Research & Development (R&D) funding**: Support for R&D initiatives can help overcome technical barriers, extending the applicability of HTHPs to higher temperature ranges and diverse industrial processes.

Demand-side measures

- **Pilot projects and Demonstration (P&D) programs**: These initiatives are critical for proving the feasibility of HTHP applications in industrial settings. By fostering pilot installations, industries and operational personnel can gain experience with the technology, leading to wider acceptance and deployment. While the survey indicates that not all companies require such programs, some express a need for it.

- **Investment credits**: Given the widespread survey responses highlighting economic barriers, financial support for capital investments in electrification infrastructure may be an option. However, these credits should be tied to the technological maturity and designed to regress over time to stimulate learning effects, reduce specific costs, and prevent free-rider effects and inefficient lock-in to long-term financial dependency.

- **Awareness and Capacity Building**: Programs aimed at increasing industry awareness, technical knowledge, and willingness to transition to HTHPs are crucial. These efforts should include training initiatives, informational campaigns, and knowledge-sharing platforms.

- **Flexible electricity grid tariffs**: Introducing flexible grid tariffs incentivizes industries to better align their electricity consumption with production patterns and market conditions. This becomes increasingly relevant as the electrification of heat prevails and grids are strained.

4.2 Alternative gases

The use of alternative gases, such as hydrogen and biomethane, presents another viable decarbonization pathway. However, as highlighted by the survey, challenges such as cost competitiveness, infrastructure readiness, and supply chain constraints must be addressed through a well-structured policy mix. The survey has shown that HTHPs are not feasible in any case, in which case alternative gases may be an option.

Proposed policy mix

- **Infrastructure development support**: Investments in pipeline networks, storage facilities, and refuelling stations are necessary to facilitate a smooth transition to alternative gases.

- **Sector-specific mandates**: Industrial sectors with high energy demands could be prioritized for alternative gas adoption through regulatory mandates and incentives.

4.3 Wood

These policy measures aim to ensure that wood resources are allocated efficiently, prioritizing high-value applications. Instead of extensive use for room heating, wood should be directed towards sectors that require high-temperature heat, such as chemical industries and construction materials manufacturing.

Proposed policy mix

- **Regulated wood use allocation**: Implementing quotas or usage restrictions across residential, industrial, and construction sectors can ensure that wood resources are optimally distributed for maximum carbon mitigation benefits.

- **Circular economy and recycling regulations**: Strengthening policies that promote the reuse and recycling of wood materials can further optimize resource efficiency and reduce waste.

- **Expansion of the Wood Resource Policy 2030**: While the existing wood strategy (FOEN, 2021) focuses on promoting information and awareness regarding optimized cascade utilization, more binding regulations should be explored to ensure sustainable wood consumption.

- **Support for advanced biomass technologies**: Encouraging the development of advanced wood & biomass processing methods, such as pyrolysis and gasification, can enhance the value derived from these energy sources.

Despite, the role of supply chain stakeholders and technological innovations in wood processing should not be underestimated in determining the effectiveness of wood utilization for decarbonization.

4.4 Summary of policy mixes

An effective policy mix for process heat decarbonization must be tailored to the specific challenges and opportunities of each option (summary see Table 7). For electrification, a combination of supplier incentives, pilot projects, and awareness initiatives is key. Alternative gases require infrastructure investments and regulatory mandates, while wood utilization should be guided by sustainable allocation and circular economy principles.

Table 7 Comparison for Policy Mixes

Option	Advantages	Challenges	Recommended policy mix
Electrification (HTHPs)	Reduces emissions, scalable in most industries	High upfront costs, requires grid flexibility	R&D funding, investment credits, pilot projects
Alternative Gases (Hydrogen, Biomethane)	Enables high-temperature applications	Expensive infrastructure, uncertain market	Infrastructure support, regulatory incentives
Wood	Readily available, effective for high heat	Limited supply, competition with other uses	Legal allocation policies, efficiency incentives

It is important to recognize that state policies are not the sole driver of decarbonization. Our survey has shown that market forces, technological advancements, and voluntary corporate initiatives play equally significant roles in accelerating the transition to a low-carbon industrial heat sector.

A critical aspect of the policy design process is assessing the legal feasibility of these policy proposals. This includes a review of existing regulatory frameworks to determine which aspects are already covered by law, which additional policies from our proposed set are necessary, and where legal constraints may limit their implementation. This legal reality check ensures that the proposed policies are not only effective in driving technological adoption and emissions reduction but are also actionable within the current legislative landscape. Where gaps or legal barriers exist, potential avenues for regulatory adaptation or expansion will be explored to facilitate the implementation of a comprehensive and effective policy mix.

5 Legal perspective: Analysis of existing and potential regulations

Until now, process heat has hardly been analysed from a legal perspective.[5] This is because high-temperature heat is usually generated on-site using natural gas or oil, eliminating the need for extensive pipeline systems. In contrast, legal science deals with issues relating to the natural gas required for this and the process heat that is distributed via district heating networks.[6]

5.1 Overview of Current Legal Instruments in decarbonization of industry / use of energy

The Federal Act on Climate Protection Targets, Innovation and Strengthening Energy Security (KIG)[7] and a partial revision of the CO_2 Act (CO2-Gesetz)[8] came into force on January 1, 2025. After a revision of the CO_2 Act, which would have provided for a series of new levies, was rejected by the electorate in 2021, these two revisions primarily provide for incentives to reduce CO_2 emissions. Both laws are also relevant for the decarbonization of process heat.

The KIG provides for the federal government to support companies that align their business activities with the net-zero target.[9] In addition to providing advice on drawing up the roadmaps used, the Confederation can also support companies in the application of new technologies, for example in pilot and demonstration plants.[10] The Federal Assembly has approved a commitment credit (Verpflichtungskredit) of CHF 200 million per year for this purpose.[11] These funds require net-zero roadmaps from the company. The Federal Council was aware that the timetables in accordance with Art. 5 KIG in the industrial sector would not be sufficient to achieve the net-zero target. For this reason, the revised CO_2 Act provides for further measures.[12]

The CO_2 Act further develops the emissions trading system for installations in line with EU regulations. Operators of plants that use process heat can benefit from emissions trading if they increase the efficiency of their plants and switch to CO_2-free energy production.[13] Plant operators can also apply for exemption from the CO_2 levy until 2040 if they submit a decarbonization plan. This plan can be derived from the KIG roadmap but, unlike the roadmap, only concerns the fuels used in the plant.[14] The CO_2 Act also allows the CO_2 emitted at these high temperatures to be captured and stored (CCS).[15]

5.2 Electrification

Building on the policy instrument overview in Part 4, decarbonizing process heat can be achieved through electrification, especially by implementing HTHPs. In the temperature range above around 170°C, the process heat must be produced by alternative gases or by burning wood for the time being. From a legal point of view, it is therefore necessary to analyse the possibilities that can be used to encourage the industry to switch to high-temperature heat pumps on the one hand and to substitute natural gas or oil with alternative gases and wood. The use of electricity to generate heat (power-to-

[5] See for regulation on the related combustion systems Trajkova, n. 3.702.

[6] See for an overview on the market regulation of gas e.g. Magnin, n. 1191 ff. and for district heating Abegg, Musliu.

[7] Verordnung über die abschliessende Inkraftsetzung des Bundesgesetzes über die Ziele im Klimaschutz, die Innovation und die Stärkung der Energiesicherheit, vgl. dazu Medienmitteilung des Bundesrats vom 27. November 2024, https://www.admin.ch/gov/de/start/dokumentation/medienmitteilungen.msg-id-103329.html.

[8] CO2-Gesetz, Änderung vom 15. März 2024, AS 2024 376.

[9] Art. 5 KIG.

[10] Art. 6 KIG; vgl. auch Botschaft CO2-Gesetz, 16.

[11] Bundesbeschluss über die Finanzierung der Förderung von neuartigen Technologien und Prozessen vom 15. September 2022, BBl 2022 1538.

[12] Parlamentarische Initiative Indirekter Gegenentwurf zur Gletscher-Initiative, Netto-Null-Treibhausgasemissionen bis 2050, Bericht der Kommission für Umwelt, Raumplanung und Energie des Nationalrates vom 25. April 2022, Stellungnahme des Bundesrates vom 3. Juni 2022, BBl 2022 1540, 5.

[13] Vgl. für eine Übersicht des Emissionshandelssystems BAFU, Emissionshandel.

[14] Art. 31 CO2-Gesetz; vgl. auch Botschaft CO2-Gesetz, 60.

[15] Vgl. Botschaft zur Revision des CO2-Gesetzes für die Zeit nach 2024 vom 16. September 2022, BBl 2022 2651 (Botschaft CO2-Gesetz), 13 f.

heat) is undesirable, which is legally reflected in the fact that national certificates are no longer issued for such a conversion under the current CO_2 Ordinance, unless the electricity is used for heat pumps.[16]

High-temperature heat pumps are intricate systems that require precise design tailored to their specific application, ensuring an efficient replacement for natural gas or oil-based heat generation. Depending on the system and concept, much higher costs are to be expected.[17] In addition, there are uncertainties regarding the availability of the refrigerants used in heat pumps, as the EU is discussing more restrictive regulation of these substances.[18] The industry is therefore dependent on further developing the technology in coordination with existing processes in the industry. Such projects should be promoted in order to drive forward the decarbonization of process heat.

As suggested above a comprehensive policy framework for electrification should incorporate measures on the supply-side and on the demand side. On the supply-side financial incentives, such as subsidies for suppliers, should be tied to development goals to encourage cost reduction and technological advancements. Regular evaluations should assess the necessity and impact of these subsidies on market growth. Subsidy contracts can include these goals and evaluation procedures, as legal frameworks require cost-effective subsidies with such contractual provisions.[19] Additionally, funding for R&D can help overcome technical barriers, expanding the applicability of HTHPs to higher temperature ranges and to more diverse industrial processes. The new regulation in the KIG and the CO_2 Act have a strong focus on the demand-side with road maps and emission trading. The laws also support companies in the application of new technologies, for example in P&D plants which are crucial for the adaption of HTHP's in some parts of the industry. According to the survey replies, financial support for capital investments in electrification infrastructure is less desired. These measures should be accompanied by information and training programs that raise industry awareness of these technologies and help build the necessary expertise.

The survey also highlights, that flexible electricity grid tariffs should be used to incentivizes industries to better align their electricity consumption with production patterns and market conditions. This becomes increasingly relevant as the electrification of heat prevails and grids are strained. One measure to ease the strain on the electricity grid is incorporated in the new CO_2 Act which expressly provides that subsidies can be granted for the use of solar thermal energy in the area of process heat.[20] The federal government limits funding to systems with a rated thermal output of 35 kW. These systems cannot benefit from subsidies for any reduction obligation at the same time.[21]

[16] Art. 5 para 1 lit. a and Appendix 3 lit. f CO2-Verordnung; Decision of the Federal Administrative Court A-4973/2023, 19.08.2024 E. 6.5.

[17] Bever et al., 1076 f.

[18] Bever et al., 1080

[19] Art. 1 para. 1 lit. b SuG.

[20] Art. 34 para 1 lit. e CO2-Gesetz.

[21] Art. 113e para 1 lit. b and para 2 E-CO2-Verordnung, see BAFU, CO2-Verordnung, 11 f.

5.3 Alternative gases

Renewable gas could also be used to produce process heat at high temperatures. The federal government will subsidize new plants for the production of renewable gases with CHF 60 million per year from 2025.[22] The Federal Government plans to restrict funding to biomethane.[23] Switzerland is importing biogas that is fed in abroad but does not reach Switzerland due to the pressure characteristics in the gas grid. Consequently, natural gas is physically imported, which was then subject to the CO2 levy. Since 2025, foreign biogas will also be able to be counted towards the ETS under certain conditions.[24] Pronovo will operate the corresponding clearing house.[25] However, as the gas networks are gradually being decommissioned, it can be assumed that such gases will be supplied mostly in containers in future.

5.4 Wood

Where industrial processes require higher temperatures, legal questions arise with regard to the energy sources of wood and alternative gases such as biogas. The use of wood as a sustainable energy source is increasing and is generally desirable. At the same time, wood is a scarce resource that should be used where no other energy sources are available. For these reasons, district heating networks that use wood to produce space heating should be viewed critically. Wood is already the most important domestic raw material for heat generation.[26] Although the national potential for wood production can still be increased,[27] it is limited due to forest legislation, which prescribes the sustainable use of forests.[28] In order to coordinate the use of this valuable resource, the federal government is pursuing a Wood 2030 resource policy.[29] Based on the concept of cascading use, this policy stipulates that wood should reduce CO_2 emissions, primarily as construction timber in the building sector. However, wood should also be used increasingly for heat production to replace fossil fuels as long as the type of wood is not suited for buildings. Where wood is used to generate heat, it should be used primarily in applications with high overall efficiency (Gesamtwirkungsgrad)[30]. The resource policy is primarily implemented with the Wood Action Plan, which promotes innovation projects and communication measures.[31] As far as can be seen, however, cascade use has so far been discussed primarily between construction timber and energy wood and less within the various areas of application for heat generation with wood. However, energy wood should preferably be used where there are no alternatives to replace fossil fuels. This is the case for process heat at temperatures above around 170 °C.

Since the demand for wood as a sustainable raw material will increase, it needs to be clarified whether the state could make more far-reaching provisions for the use of this resource. So far, the resource policy has been rather non-committal. Forests in Switzerland are owned by municipalities, corporations and private individuals. The constitution briefly defines the functions of the forest in Art. 77 BV. The Forest Act focuses on the protection of the forest and contains only a few provisions on the economic use of timber.[32] The use of timber in Switzerland is often in financial deficit.[33] For the timber industry, subsidies are therefore important, which are based on Art. 41 of the Forest Act. The market for wood is

[22] Art. 34a Abs. 1 Bst. d CO2-Gesetz, Änderung vom 15. März 2024, AS 2024 376 und Art. 2 para 1 lit. c Bundesbeschluss über die Förderung von erneuerbaren Energien 2025–2030 vom 29. Februar 2024, BBl 2024 1776.

[23] Art. 113c para 1 E-CO2-Verordnung, see BAFU, CO2-Verordnung, 12.

[24] Art. 15 para 3 and Art. 31 para 5 CO2-Gesetz; Art. 92f E-CO2-Verordnung, see BAFU, CO2-Verordnung, 11 f.

[25] Art. 95, 97, 101 BV.

[26] BAFU, Ressourcenpolitik Holz 2030, 35.

[27] BAFU, Ressourcenpolitik Holz 2030, 23 f.

[28] Art. 20 para 1 921.0 WaG.

[29] BAFU, Ressourcenpolitik Holz 2030.

[30] BAFU, Ressourcenpolitik Holz 2030, 34 ff.

[31] BAFU, Ressourcenpolitik Holz 2030, 39 ff.

[32] See Norer, n. 45 ff.

[33] See Norer, n. 37.

basically free and wood can generally also be imported and exported.[34] Any restrictions on the use of timber produced or traded in Switzerland therefore constitute an infringement of economic freedom under Article 27 of the Federal Constitution. The federal Legislator might be competent to pass such Legislation under Art. 89 para. 2 BV. Since this provision still leaves room for cantonal legislation also the Cantons might regulate restrictions on the use of wood for heating. In view of the practice of the Federal Court, which allows restrictions on economic freedom and the guarantee of property rights based on norms with climate policy interests, such a regulation seems to be possible under constitutional law although more research is needed on that question

The federal government is competent to regulate primary raw materials.[35] The legislator passed legislation on waste and guidelines for resource-efficient construction.[36] In the case of grey greenhouse gas emissions, it can define principles in energy law (Art. 89 para. 2 BV) and oblige cantons to introduce limits in building law.[37] The federal government is responsible for recycling of buildings and regulates building products.[38] The Cantons on the other hand are competent to regulate standards for the origin of materials and issue environmental and waste legislation in areas not regulated by federal law. Cantons are responsible for grey greenhouse gas emissions and must implement federal requirements.[39]

[34] Wood that is compliant with the Holzhandelsverordnung (HHV, SR 814.021).

[35] Art. 74 para. 1 BV.

[36] Art. 30 ff. and art. 35j USG.

[37] Art. 45 para. 3 lit. e EnG.

[38] Art. 30 ff. USG.

[39] Art. 89 para. 4 BV.

6 Synthesis, discussion and conclusion

6.1 General relevance of current frameworks and stakeholder perspectives

The current legal frameworks on the national level provide a strong foundation for industrial decarbonization. The survey results underscore the importance of these frameworks, showing that our sample of chemical, pharmaceutical and food industries are aware of relevant legal and policy instruments. Likely, this also applies to a broader sample of the industry as a whole, however, more evidence is needed to test this hypothesis.

Process heat decarbonization has yet to become a legislative priority. While recent policy developments, such as the Climate and Innovation Act (KIG) and the revised CO_2 Act, have introduced supportive measures, specific regulations tailored to industrial decarbonization options—including electrification, alternative gases, and wood utilization—are still lacking. Strengthening sector-specific regulations and targeted financial support mechanisms will be key to fostering the adoption and transition process.

The survey results provide valuable insights into the decarbonization efforts of the chemical, pharmaceutical, and food industries, highlighting key drivers, barriers, and policy relevance. While based on a limited sample, the findings still reveal important trends, such as the dominance of natural gas, the shift toward electrification, and the role of economic and infrastructural constraints in shaping energy choices. Barriers include high investment costs, long amortization periods, and technological limitations for achieving high temperatures. Additionally, space constraints and compatibility issues with existing equipment make the transition more complex. Specific regulatory challenges, such as those related to decarbonise and retrofit pharma-registered processes, further limit flexibility in adopting new energy solutions. Moreover, uncertainties regarding hydrogen availability and the distribution infrastructure for alternative gases complicate planning. To improve this situation, a common effort of the industry, energy and heat suppliers and regulators may be necessary. In addition, broader concerns about the potential scarcity of wood raise questions about the long-term reliability of these energy sources.

6.2 Analysis of legal gaps and relevant Options

6.2.1 Heat pump electrification

High-temperature heat pumps are a promising and emerging electrification solution, with several practical installations already in place in 2024, yet several barriers hinder widespread implementation. Among these are high initial investment costs, long amortisation periods, and uncertainties regarding refrigerant regulations. To encourage adoption, financial support measures—such as investment incentives and dedicated R&D funding—should be expanded. Additionally, clearer legal guidelines on refrigerant usage will be necessary (on a European level) to prevent regulatory ambiguities from slowing down deployment. The survey findings suggest that there is significant industry interest in pilot projects, which could serve as test cases for scaling up heat pump adoption. Adopting a system of subsidies that supports these pilot initiatives and integrates lessons learned into broader policy adjustments would be a step in the right direction.

6.2.2 Alternative gases

Alternative gases, including biogas and hydrogen, have the potential to reduce industrial emissions. However, the regulatory framework does not yet provide clear provisions on how these gases should be integrated into industrial applications. Policymakers should focus on defining the legal conditions for their use, ensuring compatibility with emissions trading systems, and facilitating investment in the required infrastructure. Survey responses indicate that while industries see promise in alternative gases, they remain uncertain about supply stability, cost competitiveness, and long-term regulatory commitments. Addressing these concerns will be crucial for a large-scale adoption.

6.2.3 Wood

Wood can serve as an energy source in select industrial applications. Policy could help preventing resource depletion. Based on the cascading principle, it should be ensured that wood is primarily used in high-efficiency applications such as industrial process heat rather than low-efficiency residential heating. The existing Wood Resource Policy 2030 outlines a strategic direction, but its legal mechanisms remain non-binding. Strengthening these regulations to prioritize industrial use and implementing efficiency-based allocation measures would help optimize wood utilization. The practical feasibility, implementation and need for such regulations should be assesses with relevant stakeholders of supply and demand side. Additionally, policies should promote the development of advanced wood & biomass processing technologies, ensuring that wood use supports both decarbonization goals and long-term sustainability. The federal government's competencies in regulating the production and use of wood need to be examined further.

6.3 Limitations and future research

While the proposed policy mixes for electrification, alternative fuels, and wood offer a structured framework to accelerate industrial decarbonization, they remain general recommendations. Further research is necessary to refine these policies, ensuring they are practically implementable, sector-specific, and adaptable to changing market and technological conditions.

The legal framework for such policies must be carefully designed to promote their adoption while also considering potential impacts on other relevant technologies. For instance, in certain regions where heat pumps may not be technologically feasible, wood serves as a crucial resource for decarbonizing room heating. Legislators must carefully assess these applications, weighing their benefits against each other to ensure balanced and effective implementation.

Future research can improve the level of specificity in policy design. Many suggested measures, such as investment credits, flexible grid tariffs, and infrastructure support, require additional analysis to determine optimal implementation mechanisms. For instance, investment credits must be carefully structured to phase out progressively, balancing early-stage support with long-term cost reductions while avoiding free-rider effects. Similarly, flexible electricity grid tariffs need detailed tariff models to encourage efficient energy use without imposing undue burdens on industrial consumers.

Moreover, the interaction between different policy instruments warrants further examination. The success of electrification depends not only on direct financial incentives but also on complementary regulations, training initiatives, and infrastructure expansion. For alternative gases, the relationship between supply chain investments, sector-specific mandates, and cost competitiveness requires modelling to ensure affordability and accessibility. In the case of wood utilization, the effectiveness of quotas and recycling regulations must be balanced against resource availability and sustainability concerns.

Finally, external market dynamics—such as energy price fluctuations, geopolitical risks, and evolving industrial needs—could influence policy effectiveness. Future research should explore adaptive policy mechanisms that allow for adjustments in response to economic and technological developments. By addressing these gaps, policymakers can develop more targeted, flexible, and effective regulatory frameworks that support industrial decarbonization without unintended inefficiencies or financial dependencies.

6.4 Limitations

While the survey provides valuable insights into industry needs and barriers for decarbonization, some caveats should be considered.

One key limitation is the small sample size of 13 responses, 11 of which reported process heat demand. Additionally, the focus on strategic decision-makers could skew responses toward larger companies with more resources for decarbonization. Despite the relatively small statistical population (estimated at

200–350 companies), this may limit the generalizability of the findings. Even with multiple follow-ups, including reminders and phone calls, the response rate remained low, likely due to survey fatigue and a lack of dedicated personnel for decarbonization—challenges that may reflect broader industry constraints and were also acknowledged by the collaborating industry association. Additionally, the focus on strategic decision-makers, whose demanding schedules limit availability, may have further impacted participation.

Self-selection bias may also be present, as participation was voluntary and may have attracted companies already engaged in decarbonization. However, the results show that not all respondents have implemented or even considered decarbonization options, reducing the likelihood of strong selection bias. While these limitations should be considered, the findings still provide meaningful insights. Future research with a larger, more representative sample could further strengthen the understanding of industry trends and challenges.

6.5 Conclusion

Balanced policy mixes as presented in this deliverable address both the demand and supply side and combine financial incentives with legal certainty. The stakeholder perspectives and legal analysis highlight that while existing frameworks lay the groundwork, further refinements are necessary to effectively address specific barriers in the chemical and food industries. Strengthening regulatory clarity, enhancing financial support mechanisms, and facilitating infrastructure investments will be instrumental in accelerating the transition to sustainable process heat. Nevertheless, not all the burden falls on the policymakers and regulations in place. While policy instruments such as KIG and CO_2 exemptions play a role, economic factors, customer requirements (even though cost pass-through remains difficult), and industry initiatives (e.g., SBTi) are strong drivers of decarbonization efforts. Still, companies see lower electricity prices, clarity on hydrogen policy, and improved energy or carbon storage technologies as key enablers for accelerating the transition.

Looking ahead, policymakers should ensure that legal and regulatory frameworks evolve in tandem with technological advancements, industry needs, the self-organization of the market and voluntary commitments from industries. Policymakers should focus on implementing regulatory mechanisms that facilitate the integration of alternative gases, streamline the market upscale of industrial heat pumps, and establish clear criteria for sustainable wood use. Ensuring long-term investment security through stable policy frameworks, while adapting to emerging technological advancements, notably high-efficiency electrification, will be critical for a successful industrial process heat decarbonization. Additionally, ensuring that regional and sector-specific regulatory structures support a just and economically viable transition will be crucial. By addressing these policy gaps, policymakers can provide an enabling environment, in which the barriers identified in this study can be tackled, reinforcing Switzerland’s broader decarbonization goals while maintaining industrial competitiveness and self-organization.

7 References

7.1 References of legal part Section 5

Abegg A., Musliu N. (2022). Die Fernwärmeversorgung – eine rechtliche Einordnung. Sui generis 2022. **https://doi.org/10.21257/sg.203**

BAFU (2024). Erläuternder Bericht zur Änderung der Verordnung über die Reduktion der CO2-Emissionen (CO2-Verordnung, SR 641.711).

BAFU (2021). Ressourcenpolitik Holz 2030, Strategie, Ziele und Aktionsplan Holz 2021–2026. **https://www.bafu.admin.ch/dam/bafu/de/dokumente/wald-holz/ud-umwelt-diverses/ressourcenpolitik-holz-2030.pdf.download.pdf/de_BAFU_UI-2103_RPH_bf.pdf**

BAFU (2024). Emissionshandelssystem für Betreiber von Anlagen. Ein Modul der Mitteilung des BAFU als Vollzugsbehörde zur CO2-Verordnung. Stand Januar 2024. **https://www.bafu.admin.ch/dam/bafu/de/dokumente/klima/uv-umwelt-vollzug/emissionshandelssystemehs.pdf.download.pdf/UV_1317-D_EHS-2024.pdf**

Bever P.-M., Bless F., Arpagaus C., Bertsch S. (2024). High-Temperature Heat Pumps for Industrial Use. Chemie Ingenieur Technik 2024 1001–1139. **https://doi.org/10.1002/cite.202300241**

Magnin J. (2024), Wettbewerbsrecht und Entflechtung im Infrastrukturbereich. Zürich.

Norer R. (2022), Kommentar zu Art. 1 Waldgesetz, in: Abt T. et al. (Ed.), Kommentar zum Waldgesetz, Zürich 2022

Trajkova, R. (2016). E. Haustechnik, Griffel A. et al. (Ed.), Fachhandbuch Öffentliches Baurecht. Zürich. 302–307.

7.2 References of Section 1-4

Arpagaus, C. (2019). *Hochtemperatur-Wärmepumpen - Marktübersicht, Stand der Technik und Anwendungspotenziale*. VDE Verlag. Berlin.

FOEN. (2021). *Wood Resource Policy 2030. Strategy, Objectives and Wood Action Plan 2021–2026.* Bern.

Giampietro, D., Stefanizzi, M., Fornarelli, F., Dambrosio, L., Nicolini, D., Miliozzi, A., & Camporeale, S. M. (2024). *Energy and Cost Analysis of Concentrated Solar Thermal Plants Integrated With Latent Heat Thermal Energy Storage for the Decarbonization of Industrial Processes*. American Society of Mechanical Engineers. In *Volume 6: Education; Electric Power; Energy Storage; Fans and Blowers*. https://doi.org/10.1115/GT2024-127835

Jakob, M., Melliger, M., Bagemihl, J., & Talary, Z. (2023). *Assessing decarbonization options for process heat: a techno-economic analysis*. Retrieved from https://sweet-sure.ch/wp-content/uploads/2023/05/Sure_Deliv_15-1_F.pdf

Melliger, M., Talary, Z., Jakob, M., & Berti, D. (2024). *Report on the assessment of the adoption potential of process heat decarbonization options. SWEET SURE Deliverable Report D15.2.* Bern.

Pauli-Kraft, U., Suter Thalmann, C.-L., & Aebischer, C. (2021). *Ressourcenpolitik Holz 2030 - Strategie, Ziele und Aktionsplan 2021-2026*. Bern.

Tasmin, N., Farjana, S. H., Hossain, M. R., Golder, S., & Mahmud, M. A. P. (2022). *Integration of Solar Process Heat in Industries: A Review*. *Clean Technologies*, *4*(1), 97–131. https://doi.org/10.3390/cleantechnol4010008

8 Appendix

8.1 Interviews in Detail

8.1.1 Pharma and Chemical Industry – Detailed summary

Barriers to Decarbonization

Economic Challenges: The high cost of alternative technologies, particularly hydrogen, which remains more expensive than direct electricity use hinders the implementation of these technologies. The limited availability and higher costs of renewable energy carriers, such as biogas and biomass, compared to fossil fuels has the same effect. Additionally, the dependency on subsidies and economic incentives, can create market distortions or favour niche solutions, that don't establish a resilient and future-oriented energy market.

Technical Hindrances: Limitations in current technology, such as high-temperature heat pumps and their readiness for large-scale deployment are technical hindrances that need to be resolved before the decarbonization process can fully unfold. Specific industrial processes, such as drying and neutralization, increase the challenge to decarbonize due to technical requirements like precise temperature control and contamination issues.

Additionally, infrastructure challenges, including the lack of suitable systems for hydrogen transport and storage and compatibility issues with existing systems, e.g., heat exchangers and their operational constraints, impede on the development.

Knowledge and Expertise Gaps: Varying levels of technical knowledge among stakeholders can delay the adoption of innovative solutions. Furthermore, misaligned expectations or lack of understanding from equipment manufacturers and process operators about potential decarbonization strategies are a barrier to decarbonization.

Resilience and Risk Aversion: Manufacturers often have concerns about reliability and the risks associated with experimental or unproven technologies. This leads to a reluctance to experiment in core operations due to their centrality to business processes.

Regulatory and Market Constraints: Inconsistent or limited certification systems for renewable energy sources, such as biogas imports, hinder the implementation of these technologies. Ecological concerns, such as the lifecycle impacts of biogas production (e.g., methane leaks and monoculture farming practices) should be considered when setting up certification systems.

Policy Needs and Support

Regulatory Alignment: Clear and consistent policies that incentivize renewable energy integration and discourage continued reliance on fossil fuels and harmonized international standards for renewable energy certification to facilitate cross-border trade, would further the decarbonization process.

Financial Incentives: Increased funding for research, development, and deployment of emerging technologies like hydrogen and high-temperature heat pumps and subsidies and tax incentives to lower the cost barrier for renewable technologies and infrastructure upgrades would further their implementation.

Encouraging Innovation: Support for pilot projects and test programs that reduce risks for industries exploring new technologies. Enhanced public-private partnerships to foster collaboration and knowledge transfer.

Promoting Knowledge Sharing: Educational initiatives to address knowledge gaps and align stakeholder understanding of decarbonization strategies. This includes enhanced training for process engineers and operators to optimize the use of renewable technologies.

Infrastructure Development: Investment in hydrogen infrastructure and seasonal energy storage solutions to enhance system flexibility and the development of resilient supply chains and technologies that withstand energy shocks and resource shortages would make it easier for renewable technologies to be adopted.

Scope 3 and Supply Chain Focus: Mandates for supply chain-wide decarbonization, as driven by initiatives like Science-Based Targets (SBTi) and other policies emphasizing accountability and transparency within supply chains to meet net-zero targets.

Current Political Instruments

Net-Zero Roadmaps and Climate Agreements: Many companies are guided by the global net-zero frameworks, such as the Paris Agreement, which anchor corporate and national targets to limit global warming. This orientation towards international standards is also due to the lack of clear national targets.

The net-zero roadmaps serve as both a driver and a constraint, as they set ambitious goals that may be challenging to implement without adequate support mechanisms.

Science-Based Targets and Environmental, Social, and Governance Standards: Instruments like SBTi are becoming increasingly influential for large companies, particularly in aligning corporate goals with climate science and requiring Scope 3 emissions reductions across supply chains. As more and more large companies have these targets this provides a ripple down effect down the supply chain making them more important with time.

ESG standards, though broadly adopted, vary in their implementation and influence depending on stakeholder priorities and regional regulations.

CO2 Compensation and Exemptions: Current CO_2 regulations, including exemptions for industries meeting certain criteria, can unintentionally discourage shifts from fossil fuels. For instance, cost reductions for industries using fossil fuels can undermine decarbonization efforts. These policies need reform to align financial incentives with the goal of reducing emissions comprehensively.

EU Taxonomy and Environmental Policy: The EU Taxonomy, designed to classify sustainable economic activities, provides a framework for industries to identify eligible projects for funding or investment. Its adoption in multinational corporations is driving compliance across their global operations, pushing suppliers and subsidiaries to follow suit.

Energy Efficiency and Emission Trading Systems: ETS and energy efficiency standards are cited as less effective among large industrial players, as many companies are already surpassing baseline requirements due to customer and supply chain pressures. Additionally, the voluntary nature or limited enforcement of these instruments in some contexts dilutes their impact.

National and Regional Incentives: Subsidies for renewable energy projects, while crucial, are often perceived as insufficient or unevenly distributed. Expanding these incentives, especially for high-impact technologies like hydrogen, is seen as critical. Support for local renewable energy production, such as biogas, remains limited due to resource constraints and inefficiencies in scaling production.

8.1.2 Interview Food Industry Expert

Barriers to Decarbonization

Complexity and Cost of Retrofits: Many industrial processes, especially in the food sector (e.g., dairies), historically use steam, even when lower temperatures (e.g., 60°C to produce most cheeses) suffice. Switching from steam to systems like heat pumps requires extensive retrofits, including replacing tanks, pipelines, heat exchangers, and adding energy buffers, which are costly, and the life cycle of these parts is often long so the barrier for them to be replaced is higher (payback time etc.). Furthermore, production processes would have to be reassessed and adapted as most renewable energy solutions deliver a base load, whereas fossil fuels deliver peak load energy. This and other aspects would require extensive planning, which also entails certain costs. Retrofits should be planned in a way that production isn't more complicated after the decarbonization. In addition, production downtime during retrofits is a major concern, especially for smaller companies with no backup facilities.

Space and Infrastructure Challenges: Heat pump systems require additional space for energy buffers and storage, which can be problematic, particularly for facilities in older or restricted spaces, such as heritage buildings or village centres. In these cases, steam was a way to efficiently use space as pipelines and boilers are smaller than when operating with warm water.

Regulatory Uncertainty (laws and regulation for labels/initiatives): Uncertainty about future energy policies and incentives creates hesitation. Smaller companies are often less familiar with upcoming regulations and lack resources to assess long-term benefits and consultants are reluctant to deliver, as future regulations aren't clear. (This uncertainty largely referred to CO_2-law and has been resolved with the finalization of the law in 2024).

Market Uncertainty: Fluctuations in energy prices (e.g., gas vs. electricity) complicate cost-benefit analyses, especially for technologies like heat pumps with higher upfront costs but lower operational expenses. Many smaller businesses aren't concerned with a long-term strategy or broader subjects, and concentrate on daily business, so they are led by energy prices.

Knowledge Gaps: Many smaller companies lack expertise in thermal energy systems and energy efficiency. Transitioning from fossil fuels like gas (which are straightforward and familiar) to complex systems like heat pumps or renewable energy requires specialized knowledge. So often the benefits of renewable energy go unnoticed. Insufficient awareness of energy efficiency opportunities, such as optimizing process temperatures, and mistrust of newer technologies due to anecdotal failures hinder adoption.

Technological and Logistical Challenges: First, high-temperature heat pumps (>150°C) are still in the early stages of adoption, requiring careful planning and site-specific solutions. Many existing systems operate at unnecessarily high temperatures, further reducing efficiency. Second, power grid infrastructure limitations can restrict the feasibility of electrification, especially for energy-intensive industries. This plays a role as soon as high temperature heat pumps are planned. Third, if suitable heat sources in the production process aren't available and other sources like ground heat have to be used, the COP often drops drastically. Finally, wood is only suitable if the logistics aren't too extensive. It shouldn't be bought in from e.g. east Europe to ensure sustainability and avoid travel emissions.

Risk Aversion: Smaller companies are less willing to be early adopters of emerging technologies due to perceived risks and lack of proven track records.

Dependence on Fossil Fuels: Many companies hope for future solutions like hydrogen or synthetic fuels but face challenges due to inefficiencies, scalability issues, and high costs of such alternatives. The uncertainty of how widely these renewable fuels will be available and unrealistic expectations for these fuels hinder decarbonization and implementation of currently available technologies. In addition, Renewable fuels are less efficient than direct use of electricity in heat pumps, from life cycle standpoint.

Policy and Support Needs

Financial Incentives and Funding: Transitioning to sustainable energy systems is capital-intensive. Subsidies, low-interest loans, or innovative financial products (e.g., green loans) are needed to reduce the burden, particularly for smaller businesses that struggle to secure favourable financing. These innovative financial products can also be useful to creditors with their own sustainability targets. Moreover, investment support is critical for pilot projects, which help reduce the risk perception and encourage broader adoption. Incentives are important to buffer the uncertainty of payback periods and the risk perception when implementing a project.

Strategic Planning and Support: Smaller businesses need tailored advice and clear roadmaps for decarbonization, including technology options, costs, and timelines. These businesses often expanded unit by unit with an overarching plan or system. Centralizing the heat supply and raising efficiency needs expert involvement and accurate planning. Strategic partnerships between companies, advisory bodies, and the government can address this. Furthermore, pinch analyses and energy optimization studies are helpful but need follow-up implementation plans to translate findings into actionable projects. The consultants themselves should provide high quality services and be up to date with the latest developments in the industry.

Regulatory Clarity: Clear and stable regulatory frameworks, including timelines for compliance and funding eligibility criteria, are essential for companies to plan long-term investments.

Capacity Building: There is a need for skilled professionals to design, implement, and maintain advanced energy systems. Training and upskilling for engineers, planners, and company staff are essential to address this shortage.

Focus on Smaller Businesses: Current policies often prioritize large emitters due to administrative simplicity, but SMEs cumulatively contribute significantly to emissions. Policies must include mechanisms to engage and support SMEs, such as simplified funding applications, technical support and more available financial incentives.

Role of Supply Chains and Market Pressure: Large companies and retailers (e.g., in food and automotive supply chains) are increasingly setting strict sustainability requirements for their suppliers. While this creates pressure to decarbonize, it also provides an incentive for smaller firms to align with these goals to retain clients.

Promoting Success Stories: Sharing successful examples of decarbonization projects (e.g., dairies adopting high-temperature heat pumps) helps build trust and encourages other companies to adopt similar measures. This is necessary as the negative news, naturally stick longer and better within the collective memory.

Additional Observations

Pilot Projects: Pilot projects play a crucial role in proving the viability of new technologies but often require government or institutional funding to mitigate risks.

Interim Solutions: Hybrid systems (e.g., combining renewable energy with backup fossil fuel systems) are seen as practical transitional measures to ensure reliability and address peak demand. These backup solutions possibly aren’t used often or ever but are still sensible to construct to ensure flawless production processes.

Accountability: Often businesses sign up for voluntary decarbonization targets without realizing what they entail, so these targets are never addressed or met. A certain form of accountability or even monitoring needs to evolve within the industry for the initiatives to develop their potential. -> close the performance gap

In conclusion, while there are significant barriers to industrial decarbonization, targeted policy measures, financial incentives, and capacity building can help overcome these challenges. Collaboration between companies, regulators, and financial institutions is key to driving progress toward net-zero emissions.

8.2 Survey results

8.2.1 Summaries of specific answers to barriers and drivers

Table 8 Summary of specific challenges and barriers of individual companies

Major Topic	Summary
Technological Limitations	Difficulty in achieving temperatures above 200°C; Limited technological maturity for temperatures exceeding 170°C.
Knowledge and Process Constraints	Lack of process knowledge (pinch analysis are ongoing); Insufficient waste heat streams to support energy recovery.
Economic and Investment Barriers	High investment costs combined with a low coefficient of performance (COP) make certain solutions unsuitable for energy efficiency commitments; Investment willingness only emerged after signing SBTi targets, as economic viability remains uncertain; High costs and long amortization periods for utilizing waste heat.
Infrastructure and Space Constraints	Transitioning from existing steam boilers is complex and expensive due to their reliable operation; Significant infrastructure requirements, including extensive piping and space limitations, particularly for high-temperature heat pump projects: Compatibility issues with existing process equipment designed for steam at 160°C.
Regulatory Barriers	Constraints in pharma-registered processes, adding complexity to transitioning energy sources.

Table 9 Summary of specific challenges of individual companies

Major Topic	Summary
Economic Factors	Lower electricity prices essential for heat pump viability; resistance to additional costs makes cost pass-through difficult.
Policy & Regulation	Need for clarity on hydrogen strategy (availability & pricing); impact of CO_2 taxes; influence of the European Green Deal.
External Pressures	Large customers and industry associations, including certification labels, create strong decarbonization pressure.
Technological Considerations	New electricity storage technologies for surplus energy; projects like CCS and electric boilers may seem inefficient but significantly reduce CO_2 emissions.
Challenges in Implementation	The Climate-Compatible Supply Chains Law (KLG) is seen as positive, but complex industries struggle with Net Zero due to a lack of available technologies for key applications and raw materials (Scope 3 emissions).

8.3 Rest of survey

8.3.1 Sample description

Overall, there were 14 responses to the survey, we considered of which two participants indicated that they have no need for process heat. One participant only partially answered the survey (see chapter **Error! Reference source not found.**) their responses are included in the section Status-Quo. Of the remaining 12 responses the following sectors were represented, chemical industry (6 participants), food industry (4 participants) and pharmaceutical industry (2 participants). This sample size is not fully representative for the Swiss industry sector, nevertheless the findings provide valuable insights into industry needs and barriers. The companies of the participants amongst other things produce building material, chemicals, pharmaceutical substances, nutritional supplements and grocery products. The participants who completed the survey hold different positions in their company. Amongst them project managers, division managers for energy and sustainability or corporate development, sustainability advisors and general managers. They have an average of 10 years of experience in this field, with one participant who is new to the field and one who has spent most of his career (29 years) in the sector.

8.3.2 Status-Quo

Most participants (9) have recently conducted an energy analysis with EnAW (Energie-Agentur der Wirtschaft). A few of them have reached additional target agreements.

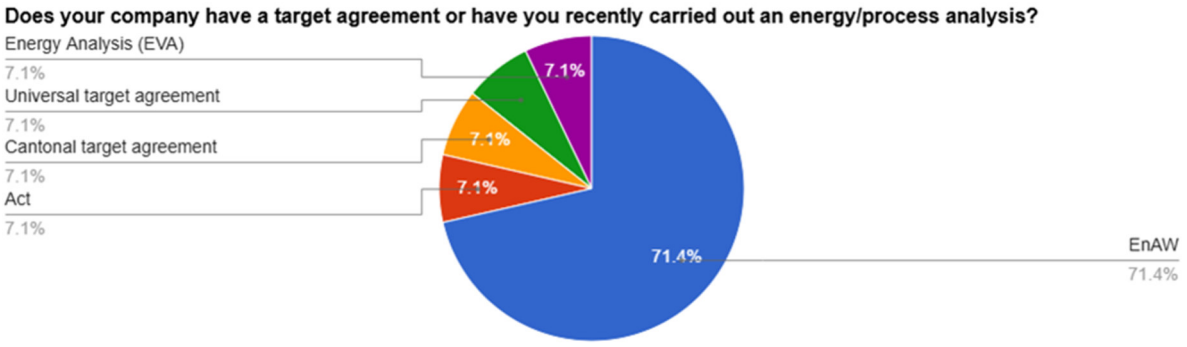

Figure 6 Percentage of target agreements that the participants have concluded (multiple answers possible, total 14 answers).

The temperature range of the needed heat is quite wide, from space heating and hot water to process heat of above 160° C. As the number of total responses exceeds 12, there are companies with multiple heat requirements in their company. Most companies also have several processes in their production that have heat requirements at a high temperature level (<80°C) (10 responses). One company has two processes, and one company has only one process that requires high temperature levels.

Table 10 Heat requirements that exist in the participants companies (multiple answers possible).

Option	Percentage	Number
Process heat up to 79°C	16.13	5
Process heat between 80°C-159°C	32.26	10
Process heat above 160°C	22.58	7
Space heating and hot water	29.03	9

The most common energy intensive processes are distillation, boiling and the concentration of products. But a variety of energy intensive processes were selected. In the “other” category the following were

listed, other chemical process, drying of chemicals, washing and precipitation with temperatures above 90°C. These energy intensive processes cover a temperature range of <120 °C to >200 °C.

Table 11 Number of responses to the most energy intensive processes in the production of participants (multiple answers possible).

Option	**Number**
Distillation	7
Compression	1
Concentration	7
Boil	7
Cook	2
Bioreactions	1
Pasteurization	2
Other	4

8.3.3 Alternative Energy sources

Table 12: Survey results for the question: "Which alternative energy sources do you consider to be possible.". The 'Ø Median' columns represent the weighted average of responses on a scale of 1 to 4 (1 = 'does not apply', etc.). All other numbers indicate the number of participants who selected each response. 'N' represents the sample size.

Question: Which alternative energy sources do you consider to be possible? **(N = 5)**	**Ø Median**	**Possible**	**More likely**	**Unclear**	**Rather not possible**	**Not possible**
Biogas	2	3	0	3	0	0
Synthetic Gas	2.8	1	1	2	0	1
Biomethane	2.6	1	1	2	1	0
Hydrogen	2	2	2	0	1	0
Wood	3.2	1	1	1	0	2
Other biomass	3.75	0	0	2	1	1
Waste	4.5	0	0	0	2	2

8.3.4 CO2 Savings and opportunities

A few participants gave insight into their CO_2 savings since decarbonizing their processes. For example, one participant reported of having reduced his CO_2 Emissions by 61% from 2013 to 2021. Another participant switched his production to using district heating from a waste incineration plant reducing his yearly emissions by approximately 85%.

The participants see a multitude of opportunities in decarbonizing their companies (see Figure 7). All participants selected the opportunity to contribute to climate protection. They also see opportunities in the direct running of the production (saving costs and resources, long-term risk protection, commercial

viability and competitive advantages) and the image of the company (investor attractiveness, cooperation opportunities and employee and customer acquisition).

The participants also gave insight into their capability to plan and carry out the decarbonization themselves. Most of them would at least partially require external companies to plan and carry out the decarbonization.

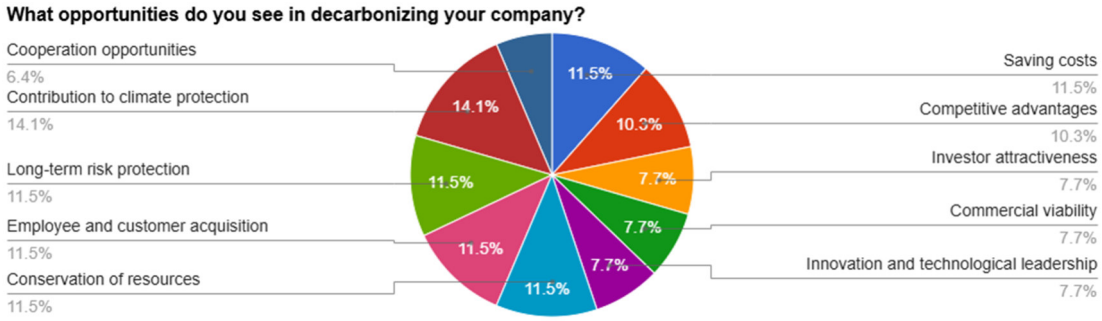

Figure 7 Percentage of opportunities that lie within the decarbonization of the participants company (multiple answers possible).

8.3.5 Role of energy suppliers

In the survey the participants were asked what utility companies could offer to facilitate the process decarbonization. Multiple participants wished for availability of renewable energy sources and a decarbonized energy network and for lower electricity prices, especially in comparison to gas prices. Additionally technical consulting and financial support were mentioned.