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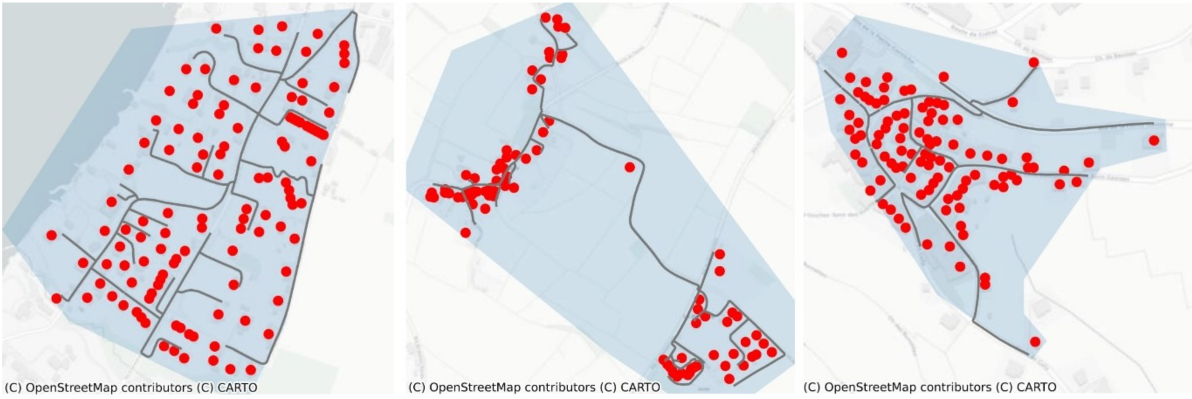
DeCarbCH



Anieres Satigny Granvaux

View on three different thermal grids using the TESSA-OSA tool

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Subsidy recipient:
University of Geneva
24 Rue du General-Dufour
1211 Geneva
https://www.unige.ch/

Consortium website: https://www.sweet-decarb.ch/

Authors:
Coordinator: Martin Patel, UNIGE, martin.patel@unige.ch
Project manager: Gianfranco Guidati, ETHZ, gguidati@ethz.ch
Silvia Ulli-Beer, ZHAW, ullb@zhaw.ch
Matthias Speich, ZHAW, spei@zhaw.ch
Madeleine Camprubi, camr@zhaw.ch
Andreas Abegg, abeg@zhaw.ch
Willy Villasmil, HSLU, willy.villasmil@hslu.ch
Beat Wellig, HSLU, beat.wellig@hslu.ch
Benjamin Ong, Benjamin.ong@hslu.ch
Stefan Bertsch, OST, stefan.bertsch@ost.ch
Frederic Bless, OST, frederic.bless@ost.ch
Cordin Arpagaus, OST, cordin.arpagaus@ost.ch
Yvonne Bäuerle, OST, yvonne.baeuerle@ost.ch
Armin Eberle, ZHAW, ebea@zhaw.ch
Gregory Houillon, HEVS, gregory.houillon@hevs.ch

SFOE project coordinators:
Laura Ding, laura.ding@bfe.admin.ch
Head of the monitoring panel: Philipp Rudolf von Rohr, philippr@ethz.ch

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The authors bear the entire responsibility for the content of this report and for the conclusions drawn therefrom.

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Executive summary

Switzerland has the ambition to reduce its greenhouse gas emissions to net-zero by the year 2050. It is well understood that the heating sector plays an essential role in the transition. Therefore, the DeCarbCH consortium focuses on the provision of heating and cooling to buildings and industrial processes, and the options for managing CO2. All aspects are embedded in an overall vision of the net-zero energy system that is quantified using energy system modelling. It integrates technical, socio-economic, and legal perspectives to ensure that proposed solutions are not only innovative and effective but also socially acceptable and legally viable.

Heating and cooling are aspects of the more technical term thermal energy. It has a quality, known as temperature. Thermal energy at high temperature is more valuable than at low temperature: it can be converted into electricity, it can be used to drive industrial processes like cement or steel production. On the other side of the temperature scale, the requirements for heating our homes or supplying domestic hot water are much lower in terms of temperature. All technological options to provide heating and cooling are therefore evaluated through this lens: not wasting a high temperature source to provide a low temperature service. Therefore the motto of DeCarbCH is: It's the temperature!

A few examples from the past and current work can illustrate these points:

- For single buildings, heat pumps are the technology of the future. A ground-source heat pump delivers 3-5 units of heat through underfloor heating for one unit of electricity to run the heat pump. However, by reducing the temperature of delivery through convective heat exchangers and by increasing the ground-source temperature through cooling in summer, this so-called coefficient of performance can be increased to beyond 10, reducing significantly the winter electricity demand.
- The same focus on temperature is applied in district heating systems. A 5^{th} generation district heating and cooling (5GDHC) network was studied with the municipality of Grandvaux (VD), highlighting the potential of this approach, namely to deliver space heat at minimal use of electricity for heat pumps while providing free cooling in summer. More such cases are currently investigated with the city of Geneva.
- While 5GDHC networks are the solution for the future, also today's existing high temperature networks can be optimized by reducing temperatures, improving their efficiency and their capability to integrated new sources like geothermal energy. This could be shown for a 2nd generation district heating system in Geneva.
- Finally, the red thread of temperature is formalized through pinch analysis in the design of industrial processes. This highlights the importance of heat recovery, the potential role of new energy sources such as geo- or solar thermal, and the options for industrial heat pumps. Two implementations of such heat pumps are expected for the near future.

As it enters the second phase, DeCarbCH will further provide key insights, practical tools, and validated strategies to drive Switzerland's heating and cooling sector toward a climate-compatible future. Even more than in the first phase, the focus will be on dissemination and outreach, as many of key insights are well-understood within the research community – but not yet outside.

Zusammenfassung

Die Schweiz hat sich zum Ziel gesetzt, ihre Treibhausgasemissionen bis zum Jahr 2050 auf netto null zu reduzieren. Es ist allgemein bekannt, dass der Heizungssektor eine wesentliche Rolle bei der Umstellung spielt. Daher konzentriert sich das DeCarbCH-Konsortium auf die Bereitstellung von Heizung und Kühlung für Gebäude und industrielle Prozesse sowie auf die Möglichkeiten zur CO2-Speicherung. Alle Aspekte sind in einer Gesamtvision des Netto-Null-Energiesystems eingebettet, die mithilfe von Energiesystemmodellen quantifiziert wird. Es integriert technische, sozioökonomische und rechtliche Perspektiven, um sicherzustellen, dass die vorgeschlagenen Lösungen nicht nur innovativ und effektiv, sondern auch sozial akzeptabel und rechtlich umsetzbar sind.

Heizung und Kühlung sind Aspekte des technischen Begriffs „thermische Energie". Diese hat eine Eigenschaft, die als Temperatur bezeichnet wird. Thermische Energie ist bei hohen Temperaturen wertvoller als bei niedrigen Temperaturen: Sie kann in Strom umgewandelt und für industrielle Prozesse wie die Zement- oder Stahlproduktion genutzt werden. Auf der anderen Seite der Temperaturskala sind die Anforderungen an die Beheizung unserer Häuser oder die Versorgung mit Warmwasser in Bezug auf die Temperatur viel geringer. Alle technologischen Optionen zur Bereitstellung von Heizung und Kühlung werden daher unter diesem Gesichtspunkt bewertet: keine Verschwendung einer Hochtemperaturquelle für die Bereitstellung einer Niedertemperatur-dienstleistung. Daher lautet das Motto von DeCarbCH: Es kommt auf die Temperatur an!

Einige Beispiele aus der bisherigen und aktuellen Arbeit können diese Punkte veranschaulichen:

- Für einzelne Gebäude sind Wärmepumpen die Technologie der Zukunft. Eine Erdwärmepumpe liefert 3-5 Einheiten Wärme über eine Fussbodenheizung für eine Einheit Strom, die zum Betrieb der Wärmepumpe benötigt wird. Durch die Reduzierung der Liefer-Temperatur über konvektive Wärmetauscher und die Erhöhung der Erdwärmetemperatur durch Kühlung im Sommer kann dieser sogenannte Leistungskoeffizient jedoch auf über 10 erhöht werden, wodurch der Strombedarf im Winter erheblich reduziert wird.
- Der gleiche Fokus auf die Temperatur gilt auch für Fernwärmesysteme. In Zusammenarbeit mit der Gemeinde Grandvaux (VD) wurde ein Fernwärme- und -kältenetz der 5. Generation (5GDHC) untersucht, dass das Potenzial dieses Ansatzes verdeutlicht, nämlich Raumwärme bei minimalem Stromverbrauch für Wärmepumpen zu liefern und gleichzeitig im Sommer eine freie Kühlung zu ermöglichen. Weitere Fälle werden derzeit mit der Stadt Genf untersucht.
- Während 5GDHC-Netze die Lösung für die Zukunft sind, können auch die heute bestehenden Hochtemperaturnetze durch eine Senkung der Temperaturen optimiert werden, wodurch ihre Effizienz und ihre Fähigkeit zur Integration neuer Quellen wie Geothermie verbessert werden. Dies konnte für ein Fernwärmesystem der 2. Generation in Genf nachgewiesen werden.
- Schliesslich wird die Bedeutung der Temperatur durch die Pinch-Analyse bei der Gestaltung industrieller Prozesse formalisiert. Dies unterstreicht die Bedeutung der Wärmerückgewinnung, die potenzielle Rolle neuer Energiequellen wie Geo- oder Solarthermie und die Möglichkeiten für industrielle Wärmepumpen. Zwei Implementierungen solcher Wärmepumpen werden in naher Zukunft erwartet.

Mit Beginn der zweiten Phase wird DeCarbCH weitere wichtige Erkenntnisse, praktische Instrumente und validierte Strategien liefern, um den Heiz- und Kühlungssektor der Schweiz in eine klimaverträgliche Zukunft zu führen. Noch mehr als in der ersten Phase wird der Schwerpunkt auf der Verbreitung und Öffentlichkeitsarbeit liegen, da viele der wichtigsten Erkenntnisse innerhalb der Forschungsgemeinschaft gut verstanden sind – ausserhalb jedoch noch nicht.

Résumé

La Suisse a pour ambition de réduire ses émissions de gaz à effet de serre à zéro d'ici 2050. Il est bien connu que le secteur du chauffage joue un rôle essentiel dans cette transition. C'est pourquoi le consortium DeCarbCH se concentre sur l'approvisionnement en chauffage et en refroidissement des bâtiments et des processus industriels, ainsi que sur les options de gestion du CO2. Tous ces aspects s'inscrivent dans une vision globale du système énergétique à zéro émission, quantifiée à l'aide d'une modélisation du système énergétique. Elle intègre des perspectives techniques, socio-économiques et juridiques afin de garantir que les solutions proposées soient non seulement innovantes et efficaces, mais aussi socialement acceptables et juridiquement viables.

Le chauffage et le refroidissement sont des aspects du terme plus technique d'énergie thermique. Celle-ci possède une qualité, appelée température. L'énergie thermique à haute température est plus précieuse qu'à basse température : elle peut être convertie en électricité, elle peut être utilisée pour processus industriels tels que la production de ciment ou d'acier. À l'autre extrémité de l'échelle de température, les besoins en chauffage de nos maisons ou en eau chaude sanitaire sont beaucoup moins élevés en termes de température. Toutes les options technologiques permettant de fournir du chauffage et du refroidissement sont donc évaluées sous cet angle : ne pas gaspiller une source à haute température pour fournir un service à basse température. C'est pourquoi la devise de DeCarbCH est : « C'est la température qui compte !

Quelques exemples tirés de travaux passés et actuels peuvent illustrer ces points :

- Pour les bâtiments individuels, les pompes à chaleur sont la technologie de l'avenir. Une pompe à chaleur géothermique fournit 3 à 5 unités de chaleur par le biais d'un chauffage au sol pour une unité d'électricité nécessaire au fonctionnement de la pompe à chaleur. Cependant, en réduisant la température de distribution par le biais d'échangeurs de chaleur convectifs et en augmentant la température géothermique par le biais du refroidissement en été, ce coefficient de performance peut être augmenté au-delà de 10, ce qui réduit la demande en électricité en hiver.
- La même attention à la température est appliquée dans les systèmes de chauffage urbain. Un réseau de chauffage et de refroidissement de 5e génération (5GDHC) a été étudié avec la municipalité de Grandvaux (VD), mettant en évidence le potentiel de cette approche, à savoir fournir du chauffage avec une consommation minimale d'électricité pour les pompes à chaleur tout en offrant un refroidissement gratuit en été. D'autres cas de ce type sont actuellement étudiés avec la ville de Genève.
- Si les réseaux 5GDHC sont la solution pour l'avenir, les réseaux à haute température existants peuvent également être optimisés en réduisant les températures, en améliorant leur efficacité et leur capacité à intégrer de nouvelles sources telles que l'énergie géothermique. Cela a pu être démontré pour un système de chauffage urbain de deuxième génération à Genève.
- Enfin, le fil rouge de la température est formalisé par une analyse de pincement dans la conception des processus industriels. Cela souligne l'importance de la récupération de chaleur, le rôle potentiel des nouvelles sources d'énergie telles que la géothermie ou l'énergie solaire thermique, et les options pour les pompes à chaleur industrielles. Deux mises en œuvre de telles pompes à chaleur sont prévues dans un avenir proche.

Alors qu'il entre dans sa deuxième phase, DeCarbCH continuera à fournir des informations clés, des outils pratiques et des stratégies validées pour orienter le secteur suisse du chauffage et du refroidissement vers un avenir compatible avec le climat. Plus encore que lors de la première phase, l'accent sera mis sur la diffusion et la sensibilisation, car bon nombre des informations clés sont bien comprises au sein de la communauté scientifique, mais pas encore en dehors.

Riassunto

La Svizzera ha l'ambizione di ridurre le emissioni di gas serra a zero entro il 2050. È ben noto che il settore del riscaldamento svolge un ruolo essenziale in questa transizione. Pertanto, il consorzio DeCarbCH si concentra sulla fornitura di riscaldamento e raffreddamento agli edifici e ai processi industriali, e sulle opzioni per la gestione della CO2. Tutti questi aspetti sono integrati in una visione globale del sistema energetico a zero emissioni, quantificata utilizzando modelli di sistemi energetici. Integra prospettive tecniche, socioeconomiche e giuridiche per garantire che le soluzioni proposte non siano solo innovative ed efficaci, ma anche socialmente accettabili e giuridicamente sostenibili.

Il riscaldamento e il raffreddamento sono aspetti del termine più tecnico "energia termica". Essa ha una qualità, nota come temperatura. L'energia termica ad alta temperatura è più preziosa di quella a bassa temperatura: può essere convertita in elettricità, può essere utilizzata per alimentare processi industriali come la produzione di cemento o acciaio. All'altra estremità della scala di temperatura, i requisiti per il riscaldamento delle nostre case o la fornitura di acqua calda sanitaria sono molto più bassi in termini di temperatura. Tutte le opzioni tecnologiche per fornire riscaldamento e raffreddamento vengono quindi valutate attraverso questa lente: non sprecare una fonte ad alta temperatura per fornire un servizio a bassa temperatura. Pertanto, il motto di DeCarbCH è: È la temperatura!

Alcuni esempi tratti dal lavoro passato e presente possono illustrare questi punti:

- Per i singoli edifici, le pompe di calore sono la tecnologia del futuro. Una pompa di calore geotermica fornisce 3-5 unità di calore attraverso il riscaldamento a pavimento per ogni unità di elettricità necessaria al funzionamento della pompa di calore. Tuttavia, riducendo la temperatura di erogazione attraverso scambiatori di calore convettivi e aumentando la temperatura geotermica attraverso il raffreddamento in estate, questo cosiddetto coefficiente di prestazione può essere aumentato oltre 10, riducendo in modo significativo la domanda di elettricità invernale.
- La stessa attenzione alla temperatura viene applicata nei sistemi di teleriscaldamento. È stata studiata una rete di teleriscaldamento e teleraffreddamento di quinta generazione (5GDHC) con il comune di Grandvaux (VD), evidenziando il potenziale di questo approccio, ovvero fornire riscaldamento degli ambienti con un uso minimo di elettricità per le pompe di calore, fornendo al contempo raffreddamento gratuito in estate. Altri casi simili sono attualmente oggetto di studio con la città di Ginevra.
- Sebbene le reti 5GDHC rappresentino la soluzione per il futuro, anche le reti ad alta temperatura esistenti oggi possono essere ottimizzate riducendo le temperature, migliorando la loro efficienza e la loro capacità di integrare nuove fonti come l'energia geotermica. Ciò è stato dimostrato per un sistema di teleriscaldamento di seconda generazione a Ginevra.
- Infine, il filo conduttore della temperatura viene formalizzato attraverso l'analisi pinch nella progettazione dei processi industriali. Ciò evidenzia l'importanza del recupero di calore, il ruolo potenziale di nuove fonti energetiche come l'energia geotermica o solare termica e le opzioni per le pompe di calore industriali. Due implementazioni di tali pompe di calore sono previste per il prossimo futuro.

Entrando nella seconda fase, DeCarbCH fornirà ulteriori approfondimenti chiave, strumenti pratici e strategie validate per guidare il settore del riscaldamento e del raffreddamento in Svizzera verso un futuro compatibile con il clima. Ancora più che nella prima fase, l'attenzione sarà rivolta alla diffusione e alla divulgazione, poiché molti degli approfondimenti chiave sono ben compresi all'interno della comunità di ricerca, ma non ancora al di fuori di essa.

1 Work programme overview

The DeCarbCH consortium addresses the colossal challenge of decarbonization of heating and cooling, both in buildings and in industry, and preparing the grounds for negative CO2 emissions. By including socio-economic and legal competencies, we seek smart, target-oriented and future-proof solutions while pursuing and prioritizing consensual approaches.

The overall objective of the consortium is to facilitate, accelerate and de-risk the implementation of renewables for heating and cooling (1) by providing guidance on which combination of technologies to implement where, to what extent and when, (2) by developing, piloting and demonstrating combinations of commercially viable technologies thereof, helping to drive down costs, (3) by conducting model-based analyses that support planning of supply, distribution and demand of renewable heating and cooling services, (4) by quantifying the value of novel technologies for reaching the Swiss climate goals, and (5) by providing evidence-based guidance on how to enable the implementation of renewable heating and cooling by policies and by legal measures as well as by engaging with the relevant actors and ensuring the necessary level of acceptance.

The work program is structured according to the following broad fields: (1) Energy system modelling at a national and local level (Workpackage WP1, WP8, WP12). The first allows to quantify the value of any type of novel technology– including negative emission technologies – for achieving the Swiss net-zero climate goal. This activity forms also the link to the other SWEET consortia, especially Cosi. The second allows to study in details the implications of heating and cooling demand, different energy sources (wood, ambient heat, etc), thermal energy storage, etc on the level of specific districts.

(2) Technological development of District Heating & Cooling (DHN) networks (WP3, WP6, WP7, WPX). Based again on a suite of detailed modelling tools, this activity addresses challenges such as network temperature reduction that allows for a better integration of renewable energy sources (ambient heat, solar, geothermal, etc), the integration of short and long term thermal energy storage, novel approaches such as thermochemical networks and generally the transition towards state-of-the art 5th generation heating and cooling networks.

(3) Introduction of novel technologies for industrial process heat (WP4, WP5, WP10, WP11). Here the focus is on proper process integration techniques such as pinch analysis. Understanding the true cooling and heating requirements forms the essential first step in any improvement of an industrial process. Only then energy efficiency measures or novel technologies can be implemented. An essential element of this activity are high-temperature industrial heat pumps that have a huge decarbonization potential when properly integrated into the process.

(4) Socio-economic and legal aspects (WP2, WP9). This activity deals with the legal risks and the long-term socio-economic dynamics of transforming the heating and cooling sector to net-zero, under consideration of expected developments in technology and market boundary conditions, as well as critical legal and socio-economic barriers and decision-making processes. It takes up solutions proposed by the technical work packages and evaluates their socio-economic and legal position. The activity takes a central position in DeCarbCH as it emphasizes the aspects of social and legal acceptance of novel technological solutions. Connecting technical, socio-economic and legal aspects, it underlines the trans-disciplinary nature of the DeCarbCH project.

The team includes the University of Geneva (coordinator), the universities of applied sciences HSLU, OST, ZHAW, HEVS, HEIG-VD and SUPSI and two federal institutions ETH Zurich and Empa. The consortium cooperates with a variety of non-academic partners, most notably the Service Industriels de Genève (SIG) and the Elektrizitätswerk der Stadt Zürich (ewz) which serve as partners for case studies on thermal networks. Several additional partners come from industry.

2 Progress of activities

In the fourth year of the project, progress was made in all fields, namely thermal heating and cooling networks, industrial process heat supply, national scale energy system modelling including negative emission technologies and the socio-economic / legal aspects that act as a bracket to the overall work.

District heating and cooling networks: Given the variety of network types, sources and sizes, a categorization into archetypes was done which allows to identify relevant test cases [1]. Based on this analysis it became especially clear that a large number of networks is based on wood firing. Since wood is a limited and exergetically valuable resource, best reserved for high temperature process heat, a key objective must be to identify pathways for district heating operators to adapt existing networks so that wood can be effectively replaced by other forms of low-grade renewable energy.

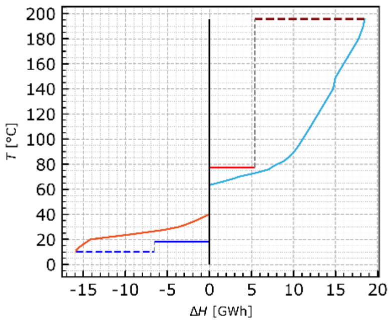
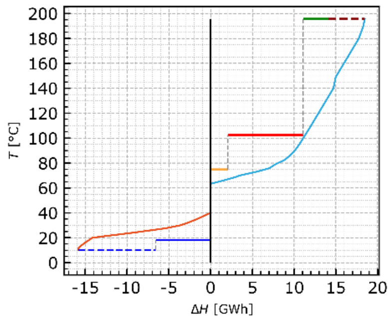
Some of these pathways were tried out on the Losone network that was identified as an archetype. (1) Options were analyzed to provide cooling along with heating services. The study examined various configurations covering solar thermal, solar PV and sorption cooling as well as compression cooling, considering different condensation strategies using outdoor air and the district heating network [2]. (2) The variant of thermochemical networks was also considered, showing the potential of TCNs to significantly increase the thermal transport capacity of DHC networks and to boost the volumetric energy density of seasonal thermal energy storage [3]. (3) The team found a widespread tendency to conservatively operate networks at unnecessarily high temperatures to ensure adequate heat supply at the building substation level, particularly under conditions of high relative heat loss (e.g., in summer when heat demand and thus flow through the network is at a minimum). This practice not only leads to inefficiencies due to increased heat losses but also hinders the integration of low-grade heat sources and heat pumps. To address this, a numerical study was conducted in WP3 to investigate the role and optimal operation of bypass valves in DH networks, again using Losone as a reference case.

In the field of industrial process heat, a methodology was developed that provides a structured framework for identifying, quantifying, and evaluating integration opportunities for energy conversion technologies and renewable technologies. This methodology is built on the principles of Pinch Analysis and applies to both continuous and non-continuous processes, ensuring a broad applicability across industrial sectors. The significance of this methodology is that it provides a transparent and standardized approach to assessing energy efficiency measures. It incorporates heat recovery potential, heat pump integration, solar thermal, and other technologies feasibility, enabling industries to systematically explore decarbonization pathways. The methodology further introduces quantification techniques incorporating techno-economic and environmental impact assessments to guide decision-making. This enables industry stakeholders to compare different integration strategies, balancing cost, energy savings, and CO_2 reduction potential. Table 1 shows two integration strategies in dairy industry that aim either at minimum costs or minimum greenhouse gas emissions.

National scale modelling using the Swiss Energyscope ETH (SES-ETH) model. Two new aspects where implemented: (1) an improved representation of electricity trade, (2) an explicit modelling of shock events. Both aspects affect the heating and cooling domain but also go beyond which makes them particularly relevant for Cosi and generally for the Swiss energy transition towards net-zero. Shock events are modelled using a so-called stochastic optimization approach. Instead of optimizing a system for one given future situation, various “futures” are defined. The optimizer then finds the optimal system configuration – sizing of assets – that works well in any of these “futures”. Here, the operation results – mostly costs and CO2 emissions – are weighted according to the likelihood that such “futures” occur. One example may be: (1) a standard future with free electricity trade – 4 out of 10 years, (2) electricity trade is hindered in the critical winter months Nov-Feb – 3 out of 10 years, (3) in addition gas imports are unavailable throughout the year due to shortage of supply – 2 out of 10 years, (4) in addition all oil imports (Diesel, gasoline, kerosene, heating oil) and electricity imports are unavailable due to a serious international crisis – 1 out of 10 years.

Figure 1 shows first results for the aforementioned scenarios. An important conclusion is that electricity generation in crisis years is best guaranteed by thermal power plants using oil, as the storage of this fuel is cheap. These plants operate as combined heat and power plants delivering also industrial process heat.

Table 1: Integration strategies for Energy conversion and renewable technologies in a dairy industry.

	Minimum Costs	Minimum emissions
		
	Heat source Heat sink Solar thermal HP Condenser HP evaporator Biomass	Geothermal Cold utility Hot utility
Total annual cost (MCHF/a)	1.1	2.2
Total annual emissions (kt-CO_2/a)	3.5	1.5
Capital expenses (MCHF)	1.0	9.2
Annual cost savings (MCHF/a)	0.5	1.2
Annual CO_2 savings (kt-CO_2/a)	1.9	4.6
Payback time (a)	2.1	21.0

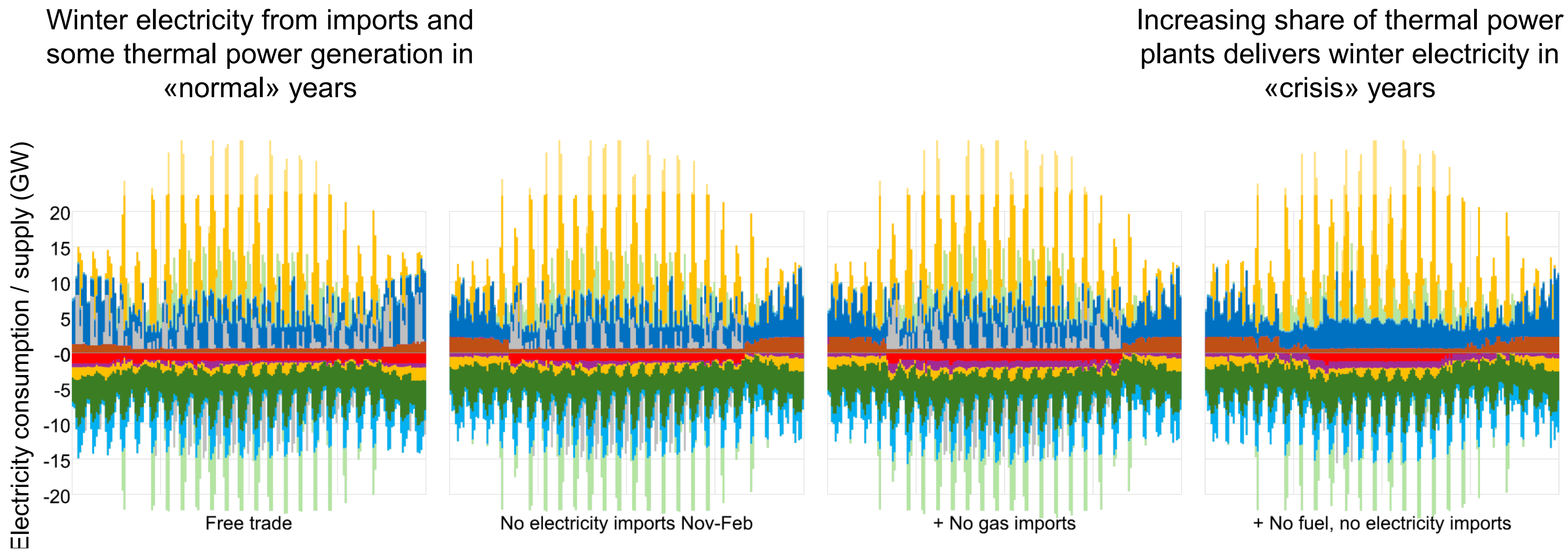


Figure 1: Hourly production and consumption of electricity; photovoltaics, pumped hydro/battery storage, hydro power, imports/exports, thermal power plants, process heat, electrolysis, heat pumps, base demand/grid losses, electric vehicles.

3 Highlights of outputs

We report here three outputs that are relevant as they directly address the needs of stakeholders: (1) the software TESSA-OSA that assists thermal grid planers and operators to design thermal grids including thermal storage, (2) a web-based practitioner tool that helps industrial companies on selecting energy efficiency measures, and (3) the system dynamic model SCOVILLE that helps to moderate transition processes in cities.

(1) TESSA has successfully reached its next stage of development by having been completely spun off from University of Geneva and now operating as an independent entity (under the company name Planeto). While the more user-friendly version of TESSA is now commercially available from Planeto, the academic version is freely available from UNIGE. This version of TESSA, called TESSA Open Source Academic (TESSA-OSA) [5], has been further developed by UNIGE to include pumping energy modelling for both single-pipe and double-pipe configurations. By applying this enhanced version of TESSA-OSA to seven municipalities, ranging from urban to rural cases, its practical operability was proven, enabling the modelling of different pipe sizes and the calculation of pumping energy. The developed model was used to address the research question of whether, and to what extent, additional buildings (that were not originally planned to be included in the district heating system) can be connected.

(2) The Practitioner Tool is a web-based application designed to support industry stakeholders in assessing the integration of energy efficiency measures and renewable technologies [6][7]. It enables users to generate energy demand profiles, identify integration opportunities for heat recovery, and evaluate potential implementations of heat pumps. The significance of this tool lies in its ability to simplify complex process integration assessments, making them accessible to industry practitioners, consultants, and SMEs. Unlike Pinch Analysis, where data collection accounts for 70-80% of the total effort, this tool eliminates the need for extensive data gathering by leveraging prepopulated energy demand profiles. This allows users to perform preliminary energy integration assessments quickly and efficiently, without requiring detailed process-level data. The tool integrates Composite Curves (CCs) and Grand Composite Curves (GCCs) to visualize heating and cooling demands, facilitating the identification of heat recovery potential and heat pump integration opportunities. By providing an intuitive interface (Figure 2) that connects methodologies developed in the project with real-world industrial applications, the Practitioner Tool serves as a bridge between research and implementation, helping industries explore feasible decarbonization strategies.

(3) The System Dynamics modelling framework SCOVILLE (Strategy Cockpits for Orchestrated Implementation of Thermal Grids in Cities and Municipalities) [8][9] is a versatile tool that can be easily parameterized to local settings and adapted to new research questions. The model simulates how KPIs (annual cash flow, market share of thermal grids and speed of heating system decarbonization) respond to decision-making by building owners, public policy interventions and the utility's pricing and financing strategies. In the next years, for example, it will be used to simulate the effect of various innovations (in accordance with the technical work packages) and policy packages on the success of municipal energy strategies. Figure 3 gives an example of the type of results that can be expected. In summary, its purpose is to: (1) Enable collective reflection on the challenges and strengths of long-term strategies to develop and operate thermal grids, (2) encourage participants to make their assumptions explicit through transparent model structure, and (3) support iterative strategic planning with a dynamic perspective.

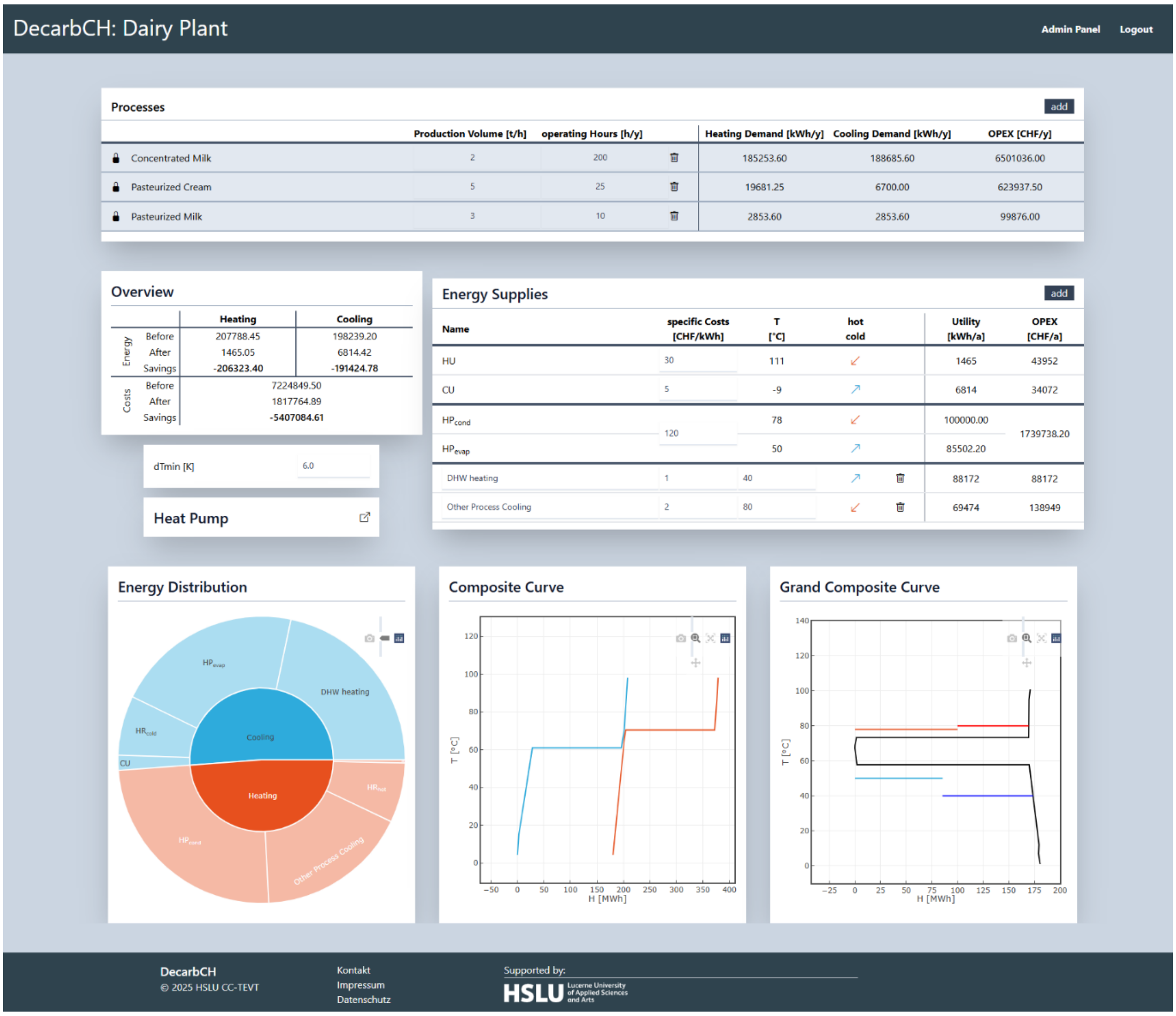


Figure 2: User-Interface for the web-based Practitioner Tool.

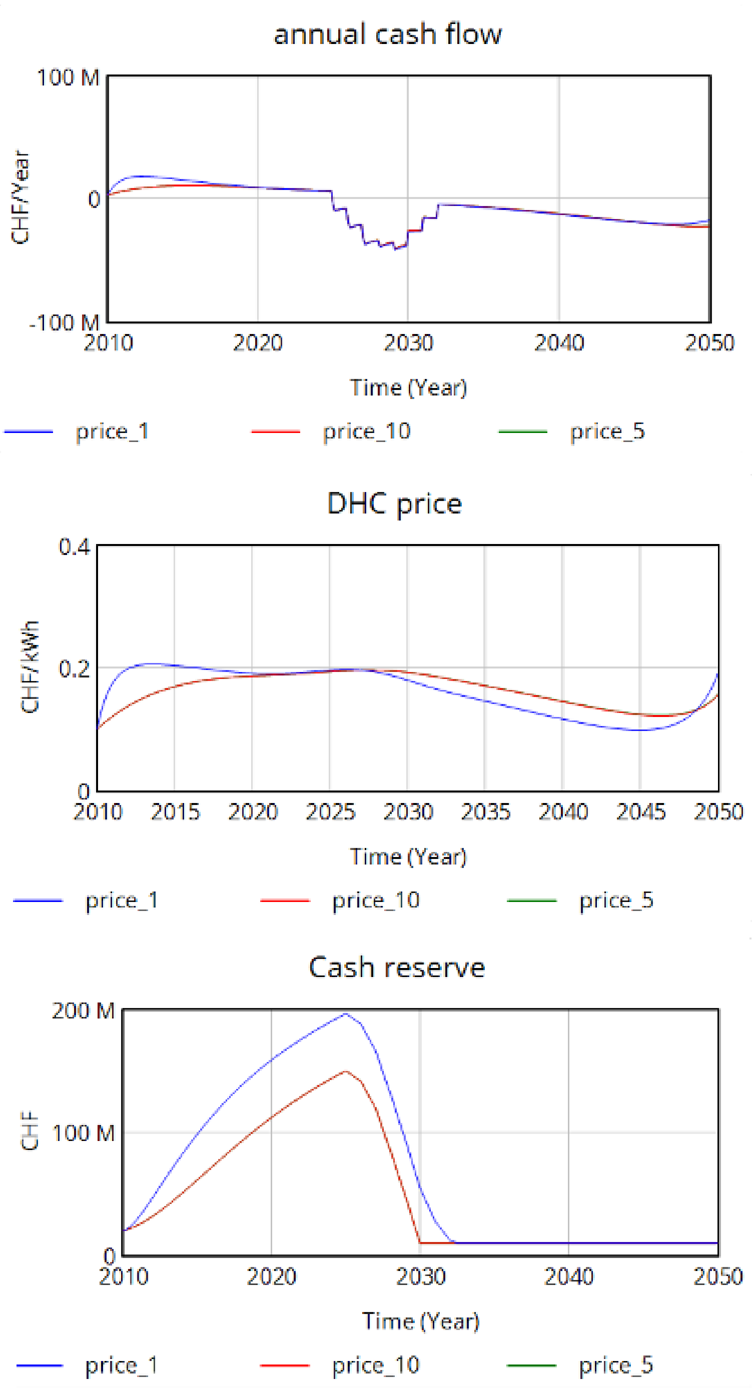


Figure 3: Evolution of financial KPIs of the district heating utility in a SCOVILLE simulation (synthetic case study). The different lines correspond to different frequencies of price adjustment.

4 References

All deliverable reports listed below (and more) can be found on the Aramis page of DeCarbCH (***https://www.aramis.admin.ch/Texte/?ProjectID=48859***).

[1] SWEET-DeCarbCH Deliverable report D3.1.1: Selection of representative districts. *Luca Brauchli et Al.*, HSLU.

[2] SWEET-DeCarbCH Deliverable report D3.2.2: Comparison of cooling capabilities of different network types and renewable sources. *Amelia Heid, Florian Ruesch*, OST-SPF.

[3] SWEET-DeCarbCH Deliverable report D3.3.2: Case study for thermochemical DHC network concept analyzed and compared to conventional hydronic network solution. *Juan Camilo Mahecha Zambrano, Luca Baldini*, ZHAW.

[4] SWEET-DeCarbCH Deliverable report D4.5.1: A method for systematic identification and quantification of opportunities for renewable heating and cooling, and energy conversion technologies. *Navdeep Bhadbhade et Al.*, HSLU-TEVT

[5] **https://gitlab.unige.ch/geneap/geneap**

[6] SWEET-DeCarbCH Deliverable report D4.2.1: Model code and documentation for practitioner tools. *Jonas Grand et Al*. HSLU.

[7] SWEET-DeCarbCH Deliverable report D4.2.2: Guidelines and instructions for practitioner tools to generate energy demand profiles. *Jonas Grand et Al*. HSLU.

[8] SWEET-DeCarbCH Deliverable report D2.3.1: Simulation model with online interface, documentation, and interactive assessment of solutions. *Matthias Speich et Al*, ZHAW.

[9] SWEET-DeCarbCH Deliverable report D2.3.2: Scenarios of sectoral implementation dynamics of the selected use cases and its temporal impact on CO2 reductions and renewable energy integration as well as strategy and policy recommendations. *Matthias Speich et Al*, ZHAW.