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Energy Research and Cleantech

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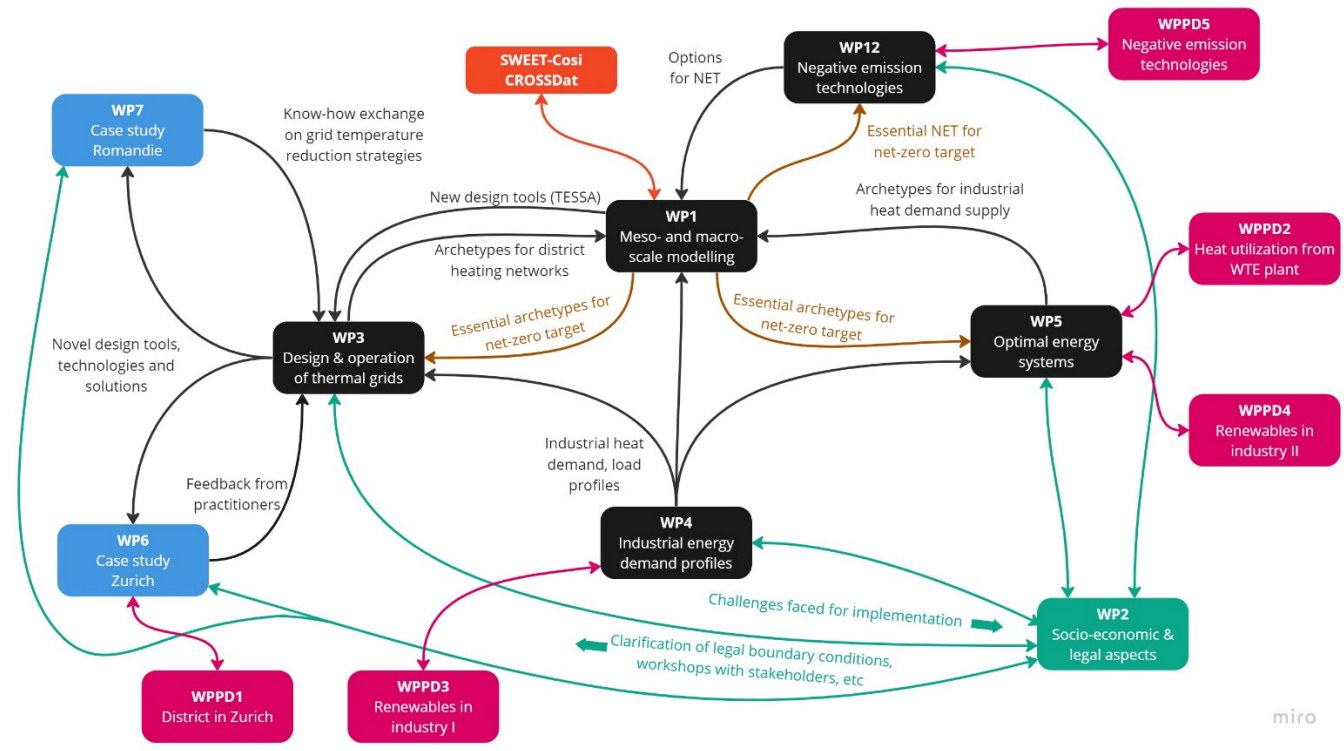
Highlights Report Year 2

DeCarbCH



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Highlights

The main highlights (results, challenges, learnings, etc.) during the reporting period were the following:

- Net-zero configurations for the energy system 2050 were generated based on the CROSS scenarios. Priorities for further development in DeCarbCH were derived, for instance the inclusion of large thermal energy storage in district heating networks with heat pumps.
- TESSA, a new software for the quick design of thermal networks is being developed in close collaboration with interested partners. The definition of district archetypes will facilitate the creation of technical guidelines for district heating networks.
- The energy demand profiles of industrial sectors were determined using process integration and statistical analysis. This is important for scoping studies to encourage industrial companies to implement optimally integrated energy efficiency measures, renewable sources and storage.
- Industrial heat pumps exhibit a huge potential for reducing the use of fossil fuels and the associated CO2 emissions in industry. The implementation of this technology is fostered by case studies with industrial partners.
- Solar thermal collectors are a sometimes forgotten technology that can deliver medium-temperature heat to districts and industrial processes. The characteristics of large collector fields were simulated and are made available through factsheets.
- Negative Emission Technologies (NETs) will play an important role in reaching the net-zero targets. The value of individual NETs was determined using energy system modelling, where the highest potential was found in CO2 separation from large point sources. Consequently, the optimal integration of the capture process is studied with industrial partners.
- A distinctive feature of DeCarbCH is the inclusion of non-technical experts in the legal and socio-economic field. This enables fruitful interactions between these domains, by highlighting the non-technical barriers and by jointly developing strategies to overcome these.
- Case studies with cities in the German and French part of Switzerland allow to quickly test and implement the tools and methods developed in DeCarbCH in practice. A detailed technical analysis of district heating networks in Geneva revealed strategies to reduce the temperature level in the network. This is an essential step for the switch from combustion based fossil systems to new energy sources as solar thermal, geothermal or large heat pumps.

Faits marquants

Les principaux faits marquants (résultats, défis, apprentissages, etc.) pendant la période de référence ont été les suivants:

- Des configurations net-zéro pour le système énergétique 2050 ont été générées sur la base du scénario CROSS. Les priorités pour le développement futur de DeCarbCH ont été déduites, par exemple l'inclusion d'un grand stockage d'énergie thermique dans les réseaux de chauffage urbain avec des pompes à chaleur.
- TESSA, un nouveau logiciel pour la conception rapide de réseaux thermiques, est en cours de développement en étroite collaboration avec les partenaires intéressés. La définition d'archétypes de districts facilitera la création de lignes directrices techniques pour les réseaux de chauffage urbain.
- Les profils de demande énergétique des secteurs industriels ont été déterminés en utilisant l'intégration des processus et l'analyse statistique. Ceci est important pour les études de cadrage afin d'encourager les entreprises industrielles à mettre en œuvre des mesures d'efficacité énergétique, des sources renouvelables et des systèmes de stockage intégrés de manière optimale.
- Les pompes à chaleur industrielles présentent un énorme potentiel de réduction de l'utilisation des combustibles fossiles et des émissions de CO2 associées dans l'industrie. La mise en œuvre de cette technologie est encouragée par des études de cas avec des partenaires industriels.
- Les capteurs solaires thermiques sont une technologie parfois oubliée qui peut fournir de la chaleur à moyenne température aux quartiers et aux processus industriels. Les caractéristiques de grands champs de capteurs ont été simulées et sont disponibles sous forme de fiches d'information.
- Les technologies à émissions négatives (NET) joueront un rôle important dans la réalisation des objectifs de zéro émission nette. La valeur des différentes TEN a été déterminée à l'aide d'une modélisation du système énergétique, et le potentiel le plus élevé a été trouvé dans la séparation du CO2 à partir de grandes sources ponctuelles. Par conséquent, l'intégration optimale du processus de capture est étudiée avec des partenaires industriels.
- Une caractéristique distinctive de DeCarbCH est l'inclusion d'experts non techniques dans les domaines juridique et socio-économique. Cela permet des interactions fructueuses entre ces domaines, en mettant en évidence les obstacles non techniques et en développant conjointement des stratégies pour les surmonter.
- Des études de cas avec des villes de Suisse allemande et française permettent de tester rapidement et de mettre en pratique les outils et les méthodes développés dans DeCarbCH. Une analyse technique détaillée des réseaux de chauffage urbain à Genève a révélé des stratégies pour réduire le niveau de température dans le réseau. Il s'agit d'une étape essentielle pour passer des systèmes fossiles basés sur la combustion à de nouvelles sources d'énergie telles que le solaire thermique, la géothermie ou les grandes pompes à chaleur.

Highlights

Die wichtigsten Highlights (Ergebnisse, Herausforderungen, Lehren usw.) während des Berichtszeitraums waren die folgenden:

- Auf der Grundlage des CROSS-Szenarios wurden Netto-Null-Konfigurationen für das Energiesystem 2050 erstellt. Es wurden Prioritäten für die weitere Entwicklungen in DeCarbCH abgeleitet, beispielsweise die Einbeziehung großer thermischer Energiespeicher in Fernwärmenetze mit Wärmepumpen.
- TESSA, eine neue Software für die schnelle Auslegung von Wärmenetzen, wird in enger Zusammenarbeit mit interessierten Partnern entwickelt. Die Definition von Distrikt-Archetypen wird die Erstellung von technischen Leitlinien für Fernwärmenetze erleichtern.
- Die Energiebedarfsprofile der Industriesektoren wurden durch Prozessintegration und statistische Analyse ermittelt. Dies ist wichtig für Scoping-Studien, um Industrieunternehmen zu ermutigen, optimal integrierte Energieeffizienzmaßnahmen, erneuerbare Energiequellen und Speicher einzusetzen.
- Industrielle Wärmepumpen weisen ein enormes Potenzial zur Reduzierung des Einsatzes fossiler Brennstoffe und der damit verbundenen CO2-Emissionen in der Industrie auf. Die Umsetzung dieser Technologie wird in Fallstudien mit Industriepartnern gefördert.
- Solarthermische Kollektoren sind eine manchmal vergessene Technologie, die Wärme im mittleren Temperaturbereich für Stadtteile und industrielle Prozesse liefern kann. Die Eigenschaften von großen Kollektorfeldern wurden simuliert und werden in Form von Factsheets zur Verfügung gestellt.
- Negative Emissionstechnologien (NETs) werden eine wichtige Rolle bei der Erreichung der Netto-Null-Ziele spielen. Der Wert der einzelnen NETs wurde mit Hilfe von Energiesystemmodellen ermittelt, wobei das höchste Potenzial in der CO2-Abscheidung aus großen Punktquellen gefunden wurde. Folglich wird die optimale Integration des Abscheidungsprozesses mit industriellen Partnern untersucht.
- Ein besonderes Merkmal von DeCarbCH ist die Einbeziehung von nichttechnischen Experten aus dem rechtlichen und sozioökonomischen Bereich. Dies ermöglicht eine fruchtbare Interaktion zwischen diesen Bereichen, indem die nichttechnischen Hindernisse aufgezeigt und gemeinsam Strategien zu deren Überwindung entwickelt werden.
- Fallstudien mit Städten in der deutschen und französischen Schweiz ermöglichen es, die in DeCarbCH entwickelten Instrumente und Methoden schnell in der Praxis zu testen und umzusetzen. Eine detaillierte technische Analyse der Fernwärmenetze in Genf zeigte Strategien zur Senkung des Temperaturniveaus im Netz auf. Dies ist ein wesentlicher Schritt für die Umstellung von verbrennungsbasierten fossilen Systemen auf neue Energiequellen wie Solarthermie, Geothermie oder Großwärmepumpen.

Punti salienti

I principali punti salienti (risultati, sfide, lezioni apprese, ecc.) durante il periodo di riferimento sono stati:

- Sono state generate configurazioni a zero emissioni per il sistema energetico 2050 sulla base dello scenario CROSS. Sono state individuate le priorità per un ulteriore sviluppo in DeCarbCH, ad esempio l'inclusione di grandi stoccaggi di energia termica nelle reti di teleriscaldamento con pompe di calore.
- TESSA, il nuovo software per la progettazione rapida di reti termiche, è in fase di sviluppo in stretta collaborazione con i partner interessati. La definizione di archetipi di distretto faciliterà la creazione di linee guida tecniche per le reti di teleriscaldamento.
- I profili della domanda energetica dei settori industriali sono stati determinati utilizzando l'integrazione dei processi e l'analisi statistica. Questo è importante per gli studi di scoping per incoraggiare le aziende industriali a implementare misure di efficienza energetica, fonti rinnovabili e stoccaggio integrate in modo ottimale.
- Le pompe di calore industriali presentano un enorme potenziale per ridurre l'uso di combustibili fossili e le relative emissioni di CO2 nell'industria. L'implementazione di questa tecnologia è promossa da casi di studio con partner industriali.
- I collettori solari termici sono una tecnologia a volte dimenticata che può fornire calore a media temperatura a distretti e processi industriali. Le caratteristiche di grandi campi di collettori sono state simulate e sono rese disponibili attraverso schede informative.
- Le tecnologie a emissioni negative (NET) svolgeranno un ruolo importante nel raggiungimento degli obiettivi di zero emissioni. Il valore delle singole NET è stato determinato utilizzando la modellazione dei sistemi energetici; il potenziale più elevato è stato riscontrato nella separazione della CO2 da grandi fonti puntuali. Di conseguenza, l'integrazione ottimale del processo di cattura è stata studiata con partner industriali.
- Una caratteristica distintiva di DeCarbCH è l'inclusione di esperti non tecnici in campo legale e socio-economico. Ciò consente interazioni proficue tra questi settori, evidenziando le barriere non tecniche e sviluppando congiuntamente strategie per superarle.
- I casi di studio con città della Svizzera tedesca e francese consentono di testare e implementare rapidamente nella pratica gli strumenti e i metodi sviluppati in DeCarbCH. Un'analisi tecnica dettagliata delle reti di teleriscaldamento a Ginevra ha rivelato strategie per ridurre il livello di temperatura nella rete. Si tratta di un passo essenziale per il passaggio dai sistemi fossili a combustione alle nuove fonti energetiche come il solare termico, la geotermia o le grandi pompe di calore.

1 Highlights of the reporting period

The DeCarbCH project addresses the challenge of decarbonising heating and cooling in Switzerland within the next three decades. The overall objective is to facilitate, speed up and de-risk the implementation of renewables for heating and cooling in the residential and in the industry sector.

We used the **CROSS scenarios[1] to characterize the energy system in 2050** and to derive insights that can be used further in DeCarbCH, especially in the technology focused work packages (see Figure below). All assumptions and scenarios are documented in the Deliverable report D1.4.1[2]. Some insights are: (1) The decarbonization of heating is mostly achieved through the electrification by heat pumps. Buildings that are not suited for heat pumps are heated with wood pellets, with some solar thermal collectors to save wood in the summer months. (2) District heating networks are fed by two main sources: waste-to-energy plants with the optional addition of gas and wood CHP plants, and with a carbon capture facility; large heat pumps that take anergy from a lake or a river. In both cases, seasonal thermal energy storage is beneficial, to improve the utilization of a valuable resource like waste, and to shift electricity consumption for heat pumps from winter to summer months. (3) Low to medium temperature process heat for industry is mostly supplied by geothermal and solar thermal energy, optionally assisted by high temperature industrial heat pumps and thermal storage. (4) Chemical energy carriers such as wood, waste, (bio-)methane or hydrogen are reserved for high temperature process heat, especially for the most demanding application in cement plants. Electrical resistance heaters play an important role, they absorb part of the photovoltaic peaks in the summer months at noon. With the help of a short-term thermal energy storage, this system can operate day and night.

Progress has been made in the field of **thermal grids**: one example is the 'Thermal Energy System Simulation Assistant (TESSA)' software (see Figure below). A project was concluded to develop a user interface and validate the industry relevance and user experience of the tool. Following positive feedback and the award of an Innosuisse/SNF BRIDGE Proof Of Concept grant, the team seeks to develop a business concept and to create a spin-off company. In collaboration with the colleagues in the socio-economic field, the team conducted interviews with stakeholders from industry and government decision makers. These had a dual role of exploring the potential of digital tools for stakeholders to understand where they see added value and to obtain feedback on the TESSA software itself. This allowed to gain valuable insight for further development and research work.

Further work on **thermal grids** aimed at identifying representative district archetypes (see Deliverable report D3.3.1[2]). A bottom-up methodology used publicly available data from the Swiss Federal Office of Energy and the Federal Register of Buildings and Dwellings. Spatial relations between thermal grids and clusters of buildings were classified and used to select the representative districts by means of a K-medoids algorithm. Thirteen input properties including the district size, the building density distribution, the share of building types, and building age were considered. Eight standardised reference district archetypes were defined (analogous to the buildings archetypes). This is an essential step to allow the outcome of the various national and international studies on thermal grids to be compared and combined into complimentary technical guidelines. Moreover, the characterization based on exergy (instead of energy) demand allows to quantify the benefits of decarbonizing measures while maximizing exergy efficiency.

[1] https://sweet-cross.ch/

[2] https://www.aramis.admin.ch/Texte/?ProjectID=48859

An important objective is to better understand the **energy demands of the Swiss industry**, and to identify and assess integration opportunities for energy efficiency measures (EEMs), renewables, and negative emission technologies (NETs). The key methodology used is Process Integration, where Pinch Analysis (PA) is the most mature tool. PA provides important insights into the absolute energy saving potential of an overall system and the measures needed to exploit this potential, for instance heat recovery, optimisation of the energy supply, use of energy conversion systems (e.g. heat pumps), and thermal energy storage. Exemplary energy profiles (grand composite curves, GCCs) that represent the heating and cooling demands and excess heat at company level for various production classes in Switzerland were constructed using statistical analysis. Aggregating these individual company profiles into sectorial source and sink profiles, aids understanding the energy requirements of the various industry sectors, in terms of quantity and quality (i.e. temperature levels). This is important for scoping studies to encourage industrial companies to implement optimally integrated EEMs, renewables and NETs. An example for a sectorial source and sink profile is shown in the Figure below for the meat subsector (see also Deliverable report D4.1.2[2]).

A key technology for the future provision of low- to medium-temperature process heat is i**ndustrial heat pumps**. Using heat pumps with the current electricity mix, a CO2 emission reduction by a factor of 5 to 7 can be achieved compared to fossil heating, adding up to 1.3 million tons CO2 annually in Switzerland. That would compensate for the total direct CO2 emissions of Zurich municipality. The long-term complete carbon neutrality can be reached for industrial heating up to 150°C. Additional benefits are reduced local particles and emissions, less overheating of lakes and rivers and inhabited space (Cooling water), and reduced noise pollution (Cooling towers). For these reasons, industrial heat pumps are also a pillar of the SFOE Heat Strategy 2050.

The characterization of **renewable energy sources** is another important task. The performance of different types of solar thermal collectors (flat plate, vacuum tube, vacuum flat and photovoltaic thermal collectors) was simulated and assessed for their typical operational conditions in Swiss district heating networks. Furthermore, best practice examples from Switzerland and abroad where reviewed. For the use in factsheets the results were summarized as monthly performance for the location Rapperswil (midlands), Davos (alpine) and Lugano (southern Switzerland).

The **value of negative emission technologies (NETs)** has been assessed with energy system modelling. It turned out that the separation of CO2 from large point sources such as waste-to-energy, cement or gas/wood CHP plants is the most valuable NET, with the largest share of stored CO2 and the highest benefit for the overall system. Consequently, this approach is developed in detail with three plant operators (see also Deliverable report D12.3.1[2]).

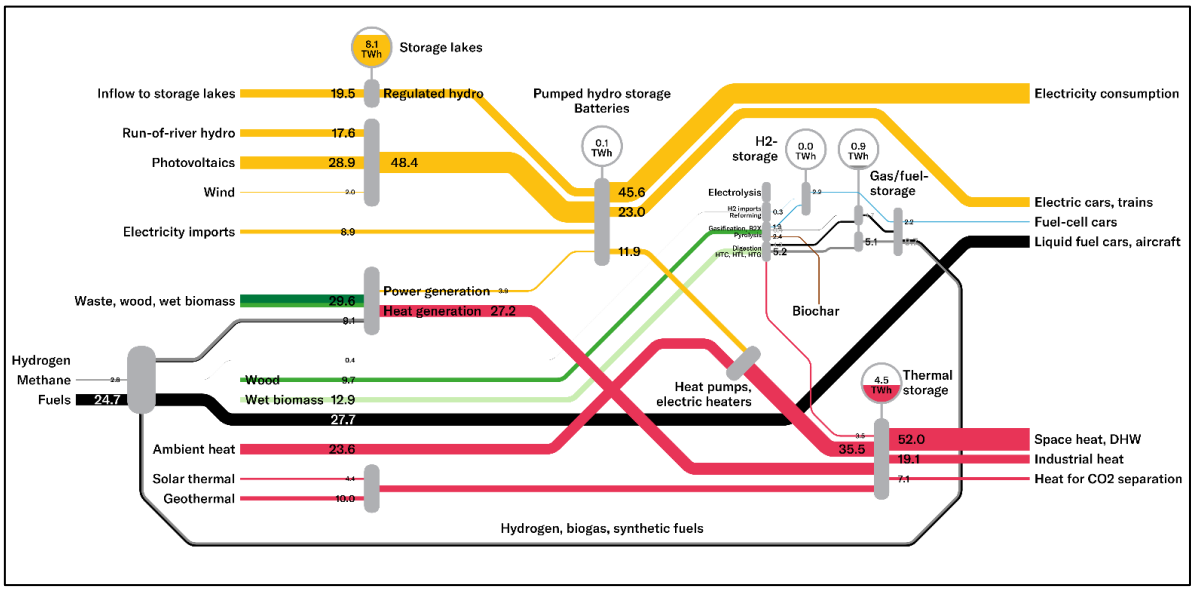
A distinctive feature of DeCarbCH is the inclusion of non-technical experts in the legal and socio-economic field. This enables fruitful interactions between these domains, by **highlighting the non-technical barriers and by jointly developing strategies to overcome these**. To structure the “messy problem” of implementing clean heating and cooling solutions, the team developed an analytical framework fostering interdisciplinary understanding of the co-evolution of a competitive business ecosystem for systemic solutions and its interplay with tailored regulations and policy solutions. By using this framework, one can systematically map the role, drivers, and challenges of technical developments, allowing to elaborate implementation strategies in specific contexts such as a city, region, or sector. Empirical research on industrial decarbonization revealed that decarbonization solutions face a complex interaction of firm-internal and external factors as drivers and barriers, such as: the firms’ sustainability orientation, demand for sound environmental strategies by customers, and a lack of knowledge and

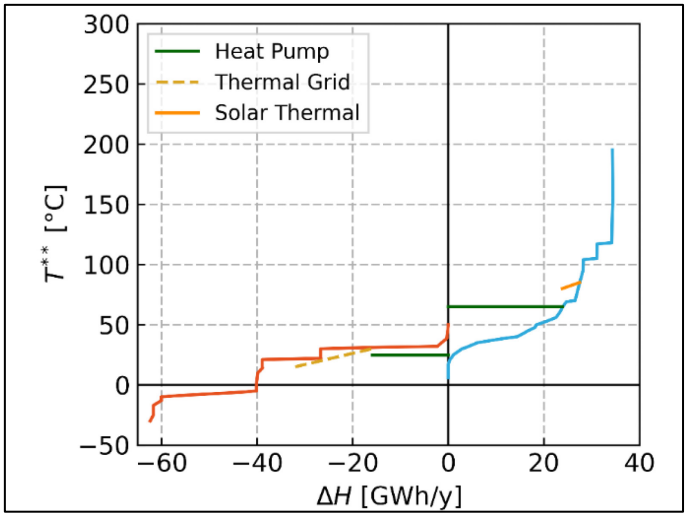
expertise. Industry associations have a potential role in assisting with knowledge transfer and matchmaking, but representativity poses a barrier to investing in offers with a focus on energy or sustainability issues.

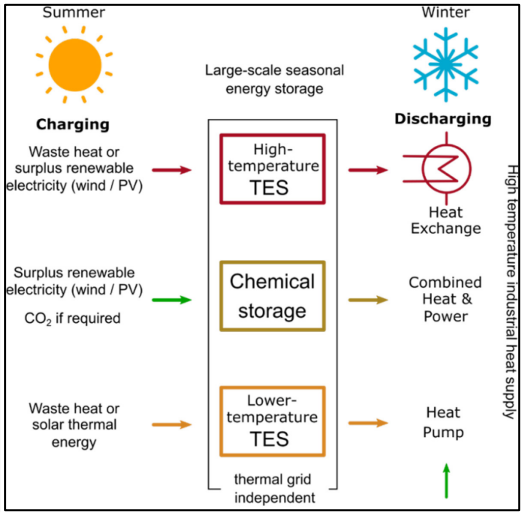
In the legal domain, there is a regulatory trend which consists in concretising existing provisions on law level by adding new provisions on ordinance level instead of revising the law. The sporadic revision of individual provisions on the level of federal Ordinances is problematic under democratic and constitutional aspects and leads in general to new legal uncertainties. On the long run, paradoxically, it seems that only a broad revision of the norms on a higher level should lead to the hoped acceleration and facilitation, even if the legislation process is slow. At least the federal spatial planning law needs an extended revision in order to facilitate and accelerate the permitting process. The ongoing and rapid changes in federal legislation require constant monitoring on one hand and flexibility in the analysis of the legal framework on the other hand. The analysis of existing energy plants serves as basis to develop guidelines and optimisation solutions for the balancing of the conflicting interests.

A further element of DeCarbCH are **case studies with cities in the German and French part of Switzerland**. Contacts in Zurich were established and topics of mutual interest were identified. These include socio-economic as well as technical issues. One example is the complex task of thermal storage integration, for example the interactions of seasonal storage elements with other energy system components or the comparison between storage solutions and demand-side -approaches. Another important common topic is the support of the city with planning tools. The DeCarbCH team has various tools that can be tested in real situations. First common projects to validate and refine such simulation models with real data from grid operators have started. Larger, area-wide and multi-producer planning is currently under discussion and will lead to comprehensive case studies.

A detailed comparative analysis of two district heating networks with **standard / optimized temperature regime** was carried out in the French part of Switzerland: i) CAD-SIG (Canton of Geneva), a large historical DH network (220 MW, 359 GWh) with high supply/return temperatures (110°C/70°C); ii) CAD Marais-Rouge (Ponts de Martel, Neuchâtel), a small rural DH network (3.5 MW, 6 GWh), with optimized supply/return temperature regime (80°C/40°C). These two district heating systems mainly supply existing (non-renovated) buildings. Auditing of selected substations of CAD SIG shows that, in most monitored cases, the high DH return temperature (>70°C) is not due to high return temperature from the buildings (usually below 45°C during the monitoring), but probably to unbalanced flowrates on primary and secondary side and/or undersized heat exchanger units. Latter result tends to show that important performance gains could be achieved with optimization of the heat exchanger control and/or size, without need to intervene on the heat storage and distribution within the buildings (see also Deliverable report D7.1.2[2])







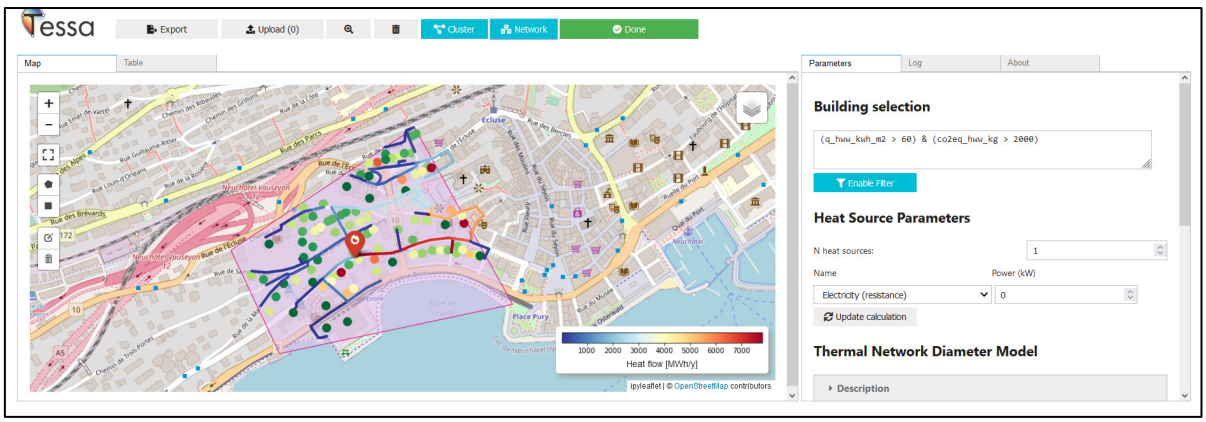


Figure: Some highlights from 2022: (1) Energy flows in a net-zero scenario for 2050; (2) source and sink profiles for the meat subsector; (3) Overview of the seasonal energy storage pathways; (4) Screenshot of TESSA web-based user interface.

2 Outputs of the reporting period

Peer-reviewed publications

Author(s), title, journal name, year	**doi**
Li, X., Walch, A., Yilmaz, S., Patel, M., & Chambers, J. (2022). Optimal spatial resource allocation in networks: Application to district heating and cooling. Computers & Industrial Engineering	**https://doi.org/10.1016/j.cie.2022.108448**
Walch, A.; Li, X.; Chambers, J.; Mohajeri, N.; Yilmaz, S.; Patel, M.; Scartezzini, J.-L.: Shallow geothermal energy potential for heating and cooling of buildings with regeneration under climate change scenarios. Energy 244 (2022)	**https://doi.org/10.1016/j.energy.2021.123086**
Hafner, S., Speich, M., Bischofberger, P., Ulli-Beer, S.: *Governing industry decarbonisation: Policy implications from a firm perspective.* Journal of Cleaner Production, 2022.	https://doi.org/10.1016/j.jclepro.2022.133884
Speich, M., Ulli-Beer, S.: Applying an ecosystem lens to low-carbon energy transitions: A conceptual framework. Journal of Cleaner Production, 2023.	https://doi.org/10.1016/j.jclepro.2023.136429
Streiff/Trajkova/Abegg, Zur Standortgebundenheit von Solaranlagen ausserhalb der Bauzone, Eine kritische Würdigung des neuen Art. 32c RPV (On the site dependency of solar energy systems outside of the building zone, a critical assessment of the new art. 32c of the Ordinance on space use planning), Jusletter September 2022, p. 1 – 18.	**https://doi.org/10.21256/zhaw-25975**
Saini, P., Ghasemi, M., Arpagaus, C., Bless, F., Bertsch, S., Zhang, X.: Techno-economic comparative analysis of solar thermal collectors and high-temperature heat pumps for industrial steam generation, Energy Conversion and Management, Volume 277, 1 February 2023	**https://doi.org/10.1016/j.enconman.2022.116623**
Giménez-Prades, P., Navarro-Esbrí, J., Arpagaus, C., Fernández-Moreno, A., Mota-Babiloni, A.: Novel molecules as working fluids for refrigeration, heat pump and organic Rankine cycle systems, Renewable and Sustainable Energy Reviews, 112549, May 2022	**https://doi.org/10.1016/j.rser.2022.112549**

Policy briefs, white papers

Author(s), title, channel or type of publication, year
Baldini, L., Guidati, G., Haller, M., Worlitschek, J. Winterstrombedarf und saisonale Wärmespeicher – mit Sommerwärme Strom im Winter sparen. Positionspapier des Forum Energiespeicher, AEE Suisse, Mai, 2022.
Luca Baldini, Jörg Worlitschek, Richard Lüchinger, Beitrag zu Abschnitt Wärmespeicher in: WÄRMESTRATEGIE 2050. Bundesamt für Energie BFE, 19.1.2023.
Ruesch, F., Bäuerle, Y., Füglister, L., Haller, M., Schmidt, T., Faktenblätter Wärmespeicher in thermischen Netzen. SPF Institut für Solartechnik, Ostschweizer Fachhochschule ost. Jan 2023

Other non-peer-reviewed publications (working papers, press articles, etc.)

Author(s), title, channel or type of publication, year
Abegg/Streiff/Trajkova, Bei den alpinen Solaranlagen geht die Planung flöten, NZZ 17.01.2023
N. Duran Adroher, R. Lüchinger, W. Villasmil, J. Worlitschek. Saisonale Wärmespeicher. Eine Schlüsseltechnologie für die Energiewende. Aqua & Gas: Fachzeitschrift für Gas, Wasser und Abwasser 11, 48-54, 01.11.2022.
Maike Schubert, Martin J. Neugebauer, Damian Birchler, Florian Ruesch and Daniel Carbonell, Buried Twin Pipe Model Validation for System Simulations of Ice Storage Tanks in 5GDHC networks, Proceedings of the Eurosun 2022, Kassel, 26.09.2022
P. Krummenacher, B.H.Y. Ong, D.G. Olsen, B. Wellig: DeCarb-PUI – Decarbonisation of Industrial Processes through Redesign of the Process-Utility Interface, S. 47-52, 28. Tagung des BFE-Forschungsprogramms «Wärmepumpen und Kältetechnik», 22. Juni 2022, BFH Burgdorf
Arpagaus, C., Paranjape, S., Brendel, L.P.M., Simoni, L.D., Kontomaris, K., Bertsch, S.S.: Experimental Investigation of R1336mzz(E) in a High-Temperature Heat Pump, 19th International Refrigeration and Air Conditioning Conference at Purdue, July 10-14, 2022, **https://docs.lib.purdue.edu/iracc/2289**
Cox, J.T., Campos, G., Armatis, P., Belding, S., Lowder, T., Kristensen, L., Zourellis, A., Bless, F., Arpagaus, C., Baldwin, S.F.: Low-Carbon District Heating: Performance Modeling of Hybrid Solar, Heat Pump and Thermal Storage Systems for District Thermal Energy in the United States, 19th International Refrigeration and Air Conditioning Conference at Purdue, July 10-14, 2022, **https://docs.lib.purdue.edu/iracc/2380**
Payá, J., Cazorla-Marín, A., Hassan, A.H., Arpagaus, C.: Techno-economic evaluation of different technologies to produce steam at 150 ºC in the Spanish industry, 12th CNIT, XII National and y III International Conference on Engineering Thermodynamics, June 29 - July 1, 2022, Madrid, Spain
Arpagaus, C., Bless, F., Bertsch, S., Krummenacher, P., Flórez-Orrego, D.A., Pina, E.A., Maréchal, F., Calame-Darbellay, N., Rognon, F., 2022. HTHP-CH – Integration of High-Temperature Heat Pumps in Swiss Industrial Processes, 28. Tagung des BFE-Forschungsprogramms «Wärmepumpen und Kältetechnik», 22. Juni 2022, BFH Burgdorf (conference flyer)
Arpagaus, C., Bless, F., Bertsch, S.: Techno-economic analysis of steam generating heat pumps for integration into distillation processes, 15th IIR-Gustav Lorentzen conference on Natural Refrigerants, June 13-15, 2022, Trondheim, Norway, **http://dx.doi.org/10.18462/iir.gl2022.0029**
Ayou, D.S., Arpagaus, C., Bertsch, S.S., Coronas, A.: Large-temperature-lift heat pumps for simultaneous heating and cooling applications in the dairy industry, 15th IIR-Gustav Lorentzen conference on Natural Refrigerants, June 13-15, 2022, Trondheim, Norway, **http://dx.doi.org/10.18462/iir.gl2022.0074**
Bless, F., Arpagaus, C. Speich, M., Bertsch, S.: Electrification of Heat Generation in Industry: State of Technologies, Integration Examples, and Integration Barriers, Young Energy Researchers Conference 2022, 5 April 2022, Wels, Austria
Arpagaus, C., Bless, F., Bertsch, S.S.: Techno-Economic Analysis of Steam-Generating Heat Pumps in Distillation Processes. 3rd High-Temperature Heat Pump Symposium, 29-30 March, 2022, Copenhagen, Denmark, **https://hthp-symposium.org**
Arpagaus, C., Payá, J., Hassan, A.H., Bertsch, S.S.: Potential Impact of Industrial High-Temperature Heat Pumps on the European Market, 29-30 March, 2022, Copenhagen, Denmark, **https://hthp-symposium.org**
Saini, P., Hedstrom, A., Arpagaus, C., Bless, F., Bertsch, S.: A hybrid system of steam generating heat pump and solar parabolic trough collectors for process heating: Techno-economic analysis for a brewery, 29-30 March, 2022, Copenhagen, Denmark, **https://hthp-symposium.org**
Fiorentini, Massimo; Vivian, Jacopo; Heer, Philipp; Baldini, Luca, 2022. Design and optimal integration of seasonal borehole thermal energy storage in district heating and cooling networks [Paper]. In: CLIMA 2022 The 14th REHVA HVAC World Congress,. 14th RHEVA HVAC World Congress, Rotterdam, The Netherlands, 22-25 May 2022. TU Delft OPEN. **https://doi.org/10.34641/clima.2022.64**

Invited talks (scientific or broad audience)

Presenter(s), title, name of the event and location, year
Speich, M. & Ulli-Beer, S.: *Urban Energy Systems as Business Ecosystems.* INUAS Conference "Urbane Transformationen: Öffentliche Räume", Winterthur, 2022.
Speich, M. & Ulli-Beer, S.: *A Business Ecosystem Perspective on Decarbonization – Preliminary Application to Thermal Energy Storage in District Heating Grids. Poster presentation,* SWEET-CROSS Event, Bern, 2023.
Willy Villasmil, Thermische Netze – Eine Schlüsseltechnologie für die Dekarbonisierung des Wärmesektors, Gebäudetechnik Kongress, Trafo Baden, 14.09.2022. (invited talk)
Jörg Worlitschek, Saisonale Wärmespeicher sollen bei Energiewende helfen, SRF-Tageschau, 30.05.2022.
Luca Baldini, Saisonale Wärmespeicher – unerlässlich?! Energie-Apéros Aargau, Baden, 18.10. / Lenzburg, 19.10. / Buchs AG, 25.10.2022. (invited talks)
Martin K. Patel, SWEET DeCarbCH - Decarbonisation of Cooling and Heating in Switzerland. 28th Swiss Heat Pump Conference (28. Tagung "News aus der Wärmepumpenforschung"), 22.6.2022
Luca Baldini, Thermische Langzeitspeicherung als wichtiger Treiber für die Energiewende – Beispiele und Erfahrungen. Geothermie-Forum Connect, Bern 28. – 29.09.2022. (invited talk)
Luca Baldini, Jörg Worlitschek, Michel Meyer, Gehen im Winter die Lichter aus – und auch die Heizungen? Sessionsveranstaltung Parlamentarische Gruppe AEE Suisse, Bern, 15.6. 2022.
Ruesch, F., Thermal Storage for Swiss District Heating Systems, IEA-SHC Swiss National Research Day 2022, Rapperswil (invited talk)
Ruesch, F., Die Rolle der Solarthermie - Lösungsansätze rund um „erneuerbare" und CO2 -arme thermische Netze, Fernwärmeforum 2023, Bern, 25. Jan. 2023. (invited talk)
B.H.Y. Ong, Construction of Sectorial Thermal Energy Profiles, Forschungsplenum 2023 – Hochschule Luzern T&A, 24th January 2023, Luzern, Switzerland
B.H.Y. Ong, M. Schubaschitz, D.G. Olsen, B. Wellig, Construction of Sectorial Thermal Energy Profiles, Proceedings of the 25th Conference on Process Integration for Energy Saving and Pollution Reduction – PRES'22, 5th to 8th September 2022, Bol, Croatia.
J. Stampfli, B.H.Y. Ong, D.G. Olsen, B. Wellig, R. Hoffmann, A Hybrid Evolutionary Algorithm for Multi-Objective Heat Exchanger Network Retrofit for Multi-Period Processes, Proceedings of the 25th Conference on Process Integration for Energy Saving and Pollution Reduction – PRES'22, 5th to 8th September 2022, Bol, Croatia.
R. Agner, B.H.Y. Ong, B. Wellig, A Bilevel Optimisation Program for the Indirect Source Sink Profile, Proceedings of the 25th Conference on Process Integration for Energy Saving and Pollution Reduction – PRES'22, 5th to 8th September 2022, Bol, Croatia.
P. Krummenacher, B.H.Y. Ong, D.G. Olsen, B. Wellig: DeCarb-PUI – Decarbonisation of Industrial Processes through Redesign of the Process-Utility Interface, S. 47-52, 28. Tagung des BFE-Forschungsprogramms «Wärmepumpen und Kältetechnik», 22. Juni 2022, Burgdorf, Switzerland.
Armin Eberle, SWEET DeCarbCH: Presentation of the case study, 33. Energielunch "Energie bewegt Winterthur", Winterthur 2022
B.H.Y. Ong, M. Schubaschitz, D.G. Olsen, B. Wellig, Construction of Sectorial Thermal Energy Profiles, Proceedings of the 25th Conference on Process Integration for Energy Saving and Pollution Reduction – PRES'22, 5th to 8th September 2022, Bol, Croatia.
J. Stampfli, B.H.Y. Ong, D.G. Olsen, B. Wellig, R. Hoffmann, A Hybrid Evolutionary Algorithm for Multi-Objective Heat Exchanger Network Retrofit for Multi-Period Processes, Proceedings of the 25th Conference on Process Integration for Energy Saving and Pollution Reduction – PRES'22, 5th to 8th September 2022, Bol, Croatia.

R. Agner, B.H.Y. Ong, B. Wellig, A Bilevel Optimisation Program for the Indirect Source Sink Profile, Proceedings of the 25th Conference on Process Integration for Energy Saving and Pollution Reduction – PRES'22, 5th to 8th September 2022, Bol, Croatia.

Completed PhD theses

Author, title, year
Stefano Cozza, *Data-driven Assessment of the Energy Performance Gap in Residential Buildings in Switzerland and Implications for Retrofit Strategies*, 2022

Completed master theses

Author, title, year
Nadia Giandeini, Justice concerns in the decarbonization of space heating in Switzerland. The case of the policy debate about the CO2 Act proposal of 2021.(2022)
S. Hochuli, Simulation of a wood-fired power plant for the optimal integration of CO_2 capture, 2023

Licences

Subject, license holder, year, brief description
PinCH Software, HSLU, 2022, Leasing and Purchase models, Software to support application of Pinch Analysis in industry

Other outputs

Brief description
Energy Optimization with Pinch Analysis course in German in 2022. The course teaches the theoretical and practical application of Pinch Analysis to examine energy use in industrial companies and how to systematically develop specific measures to increase efficiency, to optimize the utility systems, and to integrate renewables.
Individual coaching of professionals from engineering firms and industrial companies on topic of Energy Optimization with Pinch Analysis. In the reporting period, the coaching was conducted for IFEC Ingenieure SA, SPE Tech AG, Weisskopf Partner GmbH, Lippuner EMT AG, Bayer AG (Germany), Evonik Industries AG (Germany), Altana AG (Germany/Texas, US), and Croda Europe Ltd. (UK).