# IEA DHC Annex TS9

## Digitalisation of District Heating and Cooling:

### Improving Efficiency and Performance Through Data Integration

## Annex Text

Operating Agents

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# 1 Description of Technical Sector and Definition

District heating and cooling (DHC) networks are traditionally operated with a limited number of controls (as the control of the supply temperatures or the network pressure) to secure the required supply task and to optimize economics and ecologic performance. Classical network operation does not provide detailed information on the supply and utilization structures (e.g., heat plant characteristics, power demand, individual return temperatures, or time profiles). On the other hand, an optimized heat generation and overall network operation is possible with more information on the demand and flexibility options (storages) resulting in e.g. peak shaving and the reduction of expensive peak boiler use, as well as integration of fluctuation heat sources, such as solar thermal energy and power-to-heat applications operating on the electricity markets as shown by already realized projects. A wider implementation of information and communication technologies, as in many other industries, opens up for better network management based on real-time measurement data.

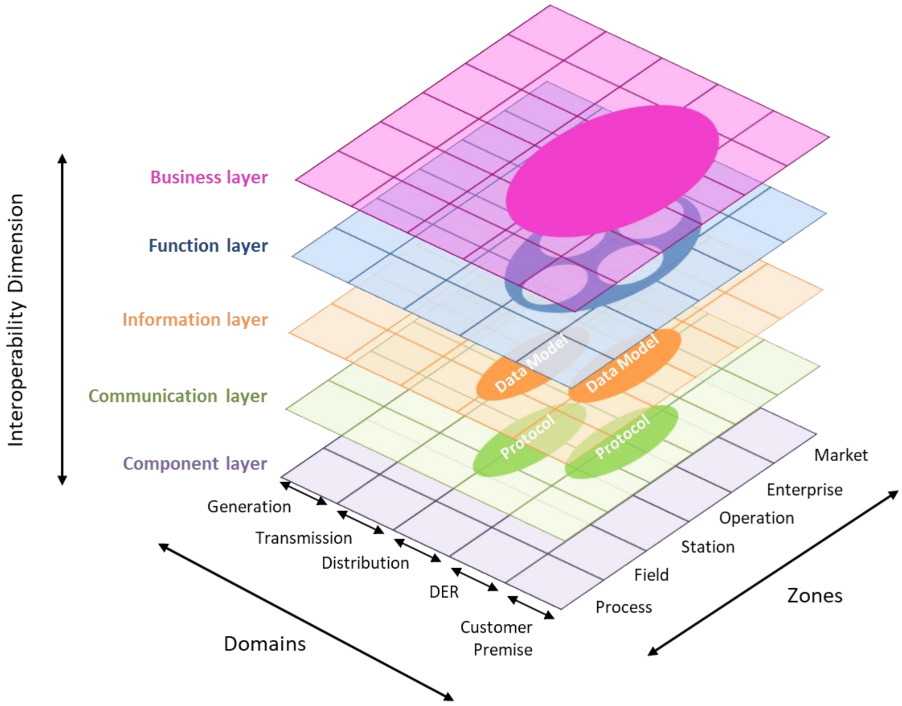



**Figure 1: Structure of the digitalisation of the energy sectors**

# 2 Scope and Objectives

## 2.1 Scope

In the transition towards a future energy system based on 100% renewable sources, the international hub for district energy research of the “International Energy Agency”

(IEA DHC) prioritized the necessity to support the development, integration, and demonstration of digital processes into district heating and cooling schemes. The future digitalization of the energy system is crucial in the global agenda and enhances district energy systems to optimize the generation and networks' operations while improving the control of heating systems inside buildings and empowering the end-consumers. The project aims to tackle existing barriers or silos hindering effective communication among various domains and stakeholders in the future advancements of DHC technology. Through this initiative, there is potential to enhance the efficiency and overall development of the 4GDH system as well as empower better-informed decision-making processes, ultimately optimizing its performance and data utilization. The results from the international collaboration will be conveyed in a practical guidebook and will be openly accessible.

## 2.2 Objectives and Challenges

The overarching IEA Annex TS9 objective is to promote new opportunities to integrate digital processes and improve the efficiency, economics, and ecological performance of district heating and cooling (DHC) networks by implementing a robust digital infrastructure. This will integrate data and signals from sensors in the different domains of the 4th generation district heating (4GDH) system with real demonstration processes. The project will focus on evaluating proper protocols and standards for data integration and helping remove barriers or silos that may be limiting the full potential of communication among different domains and agents in the future developments of DHC technology. The project may result in a more comprehensive understanding of the 4GDH system as a whole and enable more informed decision-making to optimize its performance and use of data. The project takes the entire energy chain from production/generation via distribution to end-use and consumer (secondary side systems) into account and will address the issues for both mature and emerging DHC markets.

l address the issues for both mature and emerging DHC markets.

The principal objectives of the task shared Annex can be summarized as follows:

- Create awareness of the advantages of the integration of data and signals from different domains based on robust and resilient infrastructure
- Investigate solutions for interoperability, protocols, and standardization of data communication between the involved agents and components in DHC networks.
- Evaluate non-technical barriers and enablers for digitalization processes in district heating and cooling schemes, such as business models, legal aspects, and policy instruments.
- Provide an updated state-of-the-art overview of the digitalization of district heating schemes in terms of R&D projects, demonstrators, and case studies, building further on successful IEA-DHC Annex TS4.

## 2.3 Benefits

The wider implementation of digitalization within the district heating sector offers various benefits to different stakeholders. These can be summarised as follows:

- **Utility Companies/District Heating and Cooling (DHC) Operators**: These entities form the core beneficiaries, as they are directly involved in implementing and operating heating and cooling systems. The project's findings and guidebook will empower them with description of state-of-the-art digital solutions, which enables them enhance energy efficiency, flexibility, and cost-effectiveness of their supply systems.
- **System provider**: Companies proving the necessary equipment and components for DHC- Systems are already in the markets and are offering more and more data solutions and digital services in connection with their traditional hardware products.
- **Data analytics and Service Firms:** These entities are responsible for delivering efficient data-driven solutions. The project's insights will aid them in adopting cutting-edge digital solutions to ensure optimal operations of all DHC systems.
- **Policy makers/Municipalities:** As local governing bodies, municipalities are crucial in shaping urban energy policies. The project's outcomes will offer them informed strategies for sustainable energy management and the effective utilization of local resources.
- **Scientific DHC Community:** The project's advancements will contribute to the scientific research in the district heating and cooling domain. Researchers, academics, and scholars will benefit from the project's findings.

### 2.4 State of the art and Research Issues/Novelty

The energy consumption for heating in residential, commercial, service buildings, and industry accounts for 47% of the total final energy demand [1]. Fossil fuels with 78% still have the highest share in the fuel mix, where natural gas dominates with 43% [2]. Hence, decarbonizing the heating and cooling in buildings is posing increased pressure for the green transition to tackle climate change and secure a fair energy price for the end-users due to the current high volatility of fossil fuel prices.

In the perspective of district heating and cooling (DHC) systems, due to their high flexibility to integrate diverse energy sources they can play a crucial role in the green transition of the energy market. The challenges, technically and economically, to phase out fossil-fuel based energy generation in future DHC systems requires reduction of the operating supply and return temperatures in the district heating networks to 55/25 °C, according to the definition of 4th Generation District Heating (4GDH) [3]. In the perspective of district cooling, the 4th Generation District Cooling (4GDC) was recently introduced [4]. Considering the typical design supply temperatures of 4-7 °C and smaller delta-T 9-12 °C – compared to DH networks – 4GDC aims to empower cross-sectorial integration in the energy system where cooling will play an important role, while increasing the operating temperatures [5].

In the transitions towards 4GDH and 4GDC, digital technologies are considered central to enhance the communication between different parts of the energy system, secure the energy supply in a more efficient way, optimize the system operation as well as help integrating renewable sources. A strong impulse to the digitalization in Europe was given by the EU Directive 2012/27/EU on energy efficiency (EED) – updated in 2018 with the EU EED directive 2018/2002 [6], [7]. The EED directive 2018/2002 bound EU member states to install only remotely readable devices after October 2020 and to have all existing meters remotely readable by January 2027. The approach was to convey precise information to end-users about their energy consumption for billing transparency and the effect of energy efficiency actions.

The shift from labour-intensive manual readings to cost-effective automatic data collection provides new opportunities to gain more precise insights into heating system control and operation. Volt et al. [8] highlight the technical and economic robustness of smart meters, thermostats, and sensors, which have a technology readiness level (TRL) of 9. This means that the current level of digitalization can already lead to improved operation of heating and cooling installations, paving the way for future software development with artificial intelligence (TRL 3–6) and digital twins (TRL 3–7). Artificial intelligence (AI) and machine learning (ML) can analyse large datasets, identify patterns, and make intelligent predictions, for instance optimizing the heat production schedules, predict energy demand, and dynamically adjust heat distribution based on real-time conditions. They are also central to flourishing research and development of innovative methods for optimization and fault detection and diagnosis (FDD). Faults and suboptimal operations in components and installations in DHC systems are currently among the main barriers for achieving a system with optimal low temperature operations [9], [10], [11], [12], [13]. However, despite the great potentials, very limited studies, and real applications can be found both at district energy and building level. This was clearly highlighted by the comprehensive study from Andersen et. al [14] assessing the status of automated FDD in heating, ventilation and air conditioning systems (HVAC) and how expert-rule systems are still dominant in industry.

Furthermore, there is little literature on digital twins for district heating, mainly focusing on enhancing simulation accuracy, scheduling, fault detection, and control strategies within district heating systems through the adoption of digital twin technologies. For instance, [15], [16], [17] discuss the utilization of digital twins to improve simulation and operational management in district heating networks, while [18] explore digital twin-based fault detection and prioritization in district heating systems. Various techniques such as hydraulic resistance identification, heat load prediction, and machine learning-based fault detection and optimization have been used to lead to higher operational efficiency and system reliability. Specifically, methods like the adaptive particle swarm optimization for resistance, and singular spectrum analysis with neural networks for load prediction, have been shown to enhance accuracy and reduce prediction errors [16]. Additionally, the development of detailed simulation models and predictive strategies has demonstrated the potential for increased efficiency and accuracy [15], [17]. The calibration of system parameters and fault analysis further supports the reliability and efficiency of district heating systems through digital twins [18]. Several challenges in the development of digital twins for district heating systems are highlighted in the literature, emphasizing the intricacy of modelling real-world scenarios, the criticality of data precision, the intensive computational requirements, and the necessity for seamless integration with existing infrastructures. These challenges underscore the paramount importance of data in accurately reflecting the operational dynamics of district heating systems.

Similarly, another recent survey promoted by EuroHeat&Power [19] evaluated the relevance of digitalization for actors on the district heating and cooling industry and the relative barrier and issues experienced. The findings indicate that although advanced digital solutions are available in the market, their widespread adoption remains largely untapped, especially within the design and end-user segments of the value chain.

The novelty of this project is to promote and document the new opportunities for DHC technology and address the main international technical and strategic barriers, including security and privacy issues related to the digitalization of the sector and the exchange of data between different applications, databases, and data processing platforms. A smooth integration and interoperability among different components and systems can be challenging, requiring standardized data models, protocols, and interfaces. Cooperation and coordination among international stakeholders are essential to overcome these challenges and realize the full potential of digitalization in the DHC industry. The future digitalization of energy systems is central in the global agenda and motivates this new interdisciplinary IEA DHC Annex TS9 action.

# 3 Project plan, subtasks and activities

As Annex TS9 is a task-shared annex, there will be no individual, separate research projects started within the Annex. The Annex TS9 provides a framework for the exchange of research results from international initiatives and national research projects and allows the gathering, compiling and presenting of information concerning the digitalisation of district heating and cooling systems. The Annex TS9 aims at comprehensively covering the field of a wide implementation of digital processes into the district heating industry.

To meet the objectives and overcome the challenges described in the previous chapters, all research activities presented by participants within Annex TS9 are structured, as follows, into subtasks (see Figure 2).

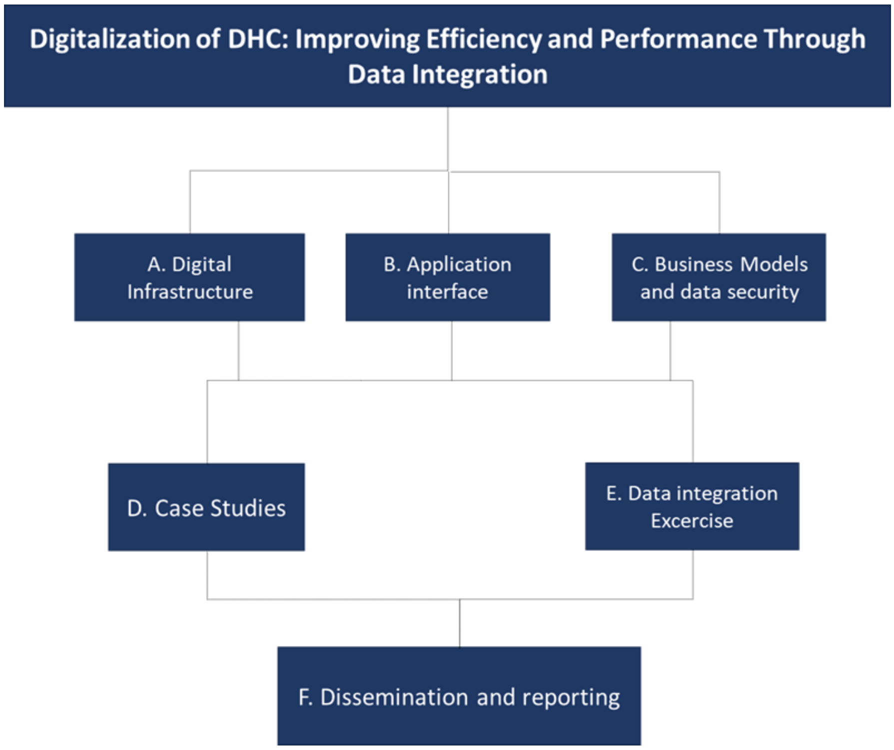



**Figure 2: Structure of the IEA-DHC Annex TS9**

### 3.1 Subtask A*: Digital Infrastructure*

**Objective**

Evaluate a comprehensive digital infrastructure augmented with an ontology-based framework to modernize the District Heating and Cooling (DHC) network, addressing the challenges faced by such systems and enabling efficient data management, analysis, and control.

**Main work items:**

- Comprehensive assessment: Conduct an in-depth evaluation of the existing DHC network infrastructure, leveraging the experiences and insights gained from the IEA DHC Annex TS4 and other international partners. Identify areas where digitalization and ontology-based approaches can offer the most significant improvements.
- Digital framework structure: Considering the heterogeneity of the DHC systems to provide an overview for integrating digital technologies, including sensors, data collection systems, communication networks, and a semantic ontology framework collecting the best practice and international experiences.
- Ontology definition: Evaluate an ontology-based framework that captures and formalizes the domain knowledge of DHC systems, facilitating semantic interoperability, data integration, and intelligent decision-making.

### *3.2* Subtask B: *Application interface*

**Objective:**

Assess standardized interfaces and interoperability mechanisms to facilitate smooth integration and interaction between various components and systems within the DHC network, enabling efficient data exchange, control, and collaboration.

**Main work items:**

- Interface standardization: Define and implement common protocols, formats, and data models for consistent data exchange and interoperability between different DHC network components and subsystems.
- API development: Evaluation of application programming interfaces (APIs) to enable smooth integration and interaction between software applications and digital infrastructure components.
- Results from current experiences: Compatibility and interoperability of interfaces with existing and future DHC network systems, highlighting compatibility issues.
- Documentation: Create comprehensive documentation and training materials to guide DHC stakeholders in implementing and utilizing the standardized interfaces effectively.

## *3.3* Subtask C: *Business models and data security*

**Objective**

Develop sustainable business models and robust data security measures to support the adoption and operation of the modernized District Heating and Cooling (DHC) network, ensuring the protection of sensitive information and fostering long-term viability.

**Main work items:**

- Conduct an analysis of existing business models within the DHC sector and identify innovative approaches to support the integration of digital technologies. Explore and analyse revenue streams, cost structures, and value propositions tailored to the modernized DHC network, and how the digitalization can sustain the transition from 3GDH to 4GDH.
- The development of innovative data- driven products is growing fast and the handling and integration of data from end-users and energy meters in software may be limited by the classification of the data as GDPR-sensitive. The coordination of a common strategy for data security and transparency must be a highly prioritized task to secure the interoperability and integration of all the various data sources in the future.
- Sustainability and Impact Assessment: Undertake comprehensive evaluations to understand the contribution of sustainable business models and robust data security practices towards achieving the primary objectives of lowering carbon emissions and improving energy efficiency within the updated District Heating and Cooling (DHC) network. These studies should encompass the environmental, economic, and social ramifications to provide a holistic view of the impacts.

## *3.4* Subtask D: *Case studies.*

**Objective**

Gather and evaluate compelling evidence from existing successful installations to demonstrate how digitalization barriers can be effectively overcome, showcasing best practices in implementation, operation, and control.

**Main work items:**

- Identify and select a diverse range of existing successful installations within the DHC systems that have effectively implemented digitalization strategies to overcome barriers and achieve desired outcomes.
- Gather comprehensive data and information on each selected case study, including project objectives, implementation strategies, technological solutions deployed, operational processes
- Analyse collected data to identify key success factors, lessons learned, and best practices associated with each case study. Document findings in detailed case study reports, highlighting insights, challenges, and recommendations for replication or adaptation.

### *3.5* Subtask E: *Data integration exercise*

**Objective**

Facilitate collaborative exercises to address specific technical issues and challenges within the digitalization of DHC systems – linked to activities of subtasks A, B, and C, fostering knowledge exchange, problem-solving, and innovation among project partners.

**Main work items:**

- Collaboratively identify and prioritize technical challenges and issues encountered during the activities of other subtasks.
- Develop structured exercises or case studies focused on addressing identified technical issues, incorporating real-world scenarios, data, and/or simulations where applicable. Define clear objectives, methodologies, and success criteria for each exercise.
- Engage project partners in collaborative investigation and analysis of technical issues through the completion of exercise tasks and activities. Encourage interdisciplinary collaboration and knowledge exchange to explore diverse perspectives and solutions.

### *3.6* Subtask F: *Dissemination and reporting*

**Objective**

Disseminate project outcomes, findings, and best practices to a wide range of stakeholders, including industry professionals, policymakers, researchers, and the general public, to promote awareness, knowledge sharing, and uptake of innovative digitalization approaches in DHC industry.

**Main work items:**

- Develop a comprehensive dissemination strategy outlining the goals, target audiences, channels, and key messages for sharing project outcomes and findings effectively.

- Facilitate knowledge sharing and exchange of experiences to promote learning and adoption of successful digitalization practices.
- Publish project findings, case studies, and research papers in peer-reviewed journals, industry magazines, technical publications and through workshop to reach a broader audience and contribute to the body of knowledge in the field.

### 3.7 Expected Results

The primary deliverable of the annex is a **practical applicable guidebook on advances in the digitalisation of district heating** for key people form the target groups. It is to contain an executive summary for decision makers.

The guidebook will be published preferably both as a book via a publisher, and as an electronic publication.

More detailed results, which will be published as appendices or separate reports via the project homepage.

In addition to the guidebook an image film about the main outcome of the Annex will be produced to spread and published via the IEA DHC YouTube channel to further spread the information.

The dissemination of documents and other information is to be focussed at transferring the research results to practitioners. Methods of information dissemination include conventional means such as presentations at workshops and practice articles. The project homepage will be used extensively to spread information. Publications may be written in English and in the languages of the participants' countries. However, the translation of the key findings into English will allow for a broader distribution of knowledge. A communication platform will be developed using local networks and energy related associations. Regular workshops will be organised in all participating countries to show the latest project results and to provide an exchange platform for the target audience. Some of the workshops might be organised within the framework of national or international conferences or symposia of the district heating community/industry. It would be beneficial to track the number of downloads from the project website to measure the success.

### 3.8 IEA DHC Annex TS9 Management

Annex TS9 is on daily basis operated by the Operating Agents under supervisory control of the Executive Committee (ExCo) of IEA DHC. The Operating Agents report twice a year to the ExCo in their meetings. The Subtasks A to F are managed by subtask leaders in a close collaboration with their co-leaders.

# 4 Operating Agent of TS9 and Subtask Leaders

The Operating Agent for Annex TS9 is Dietrich Schmidt, Fraunhofer Institute for Energy Economics and Energy System Technology / Germany and Michele Tunzi, Technical University of Denmark / Denmark. The work is on the daily basis supported by the Operating Agent of IEA DHC, Andrej Jentsch IEA DHC and German Heat & Power Association – AGFW e.V., which is acting on behalf of the ExCo of IEA DHC.

The subtask leaders are expected to be from different countries.

**Subtask A:** ***Austria*****:** represented by Edmund Widl, AIT

**Subtask B:** ***Belgium*****:** represented by Dirk Vanhoudt, Vito

**Subtask C:** ***Sweden***: represented by Kristina Lygnerud, IVL

**Subtask D:** To be Agreed

**Subtask E:** ***Denmark***: represented by Christian Holm Christiansen, DTI and supported by the Operating Agent Michele Tunzi (DTU)

**Subtask F:** ***Germany & Denmark:*** represented by the Operating Agents Dietrich Schmidt (Fraunhofer IEE) & Michele Tunzi (DTU)

# 5 Co-ordinated IEA Activities

The experts of DHC Annex TS9 are seeking a close cooperation to other IEA initiatives and TCPs (Technology Cooperation Programmes) as EBC (Energy in Buildings and Communities), HPT (Heat Pump Technology Programme) and others. Some specific cooperation activities are listed below:

## 5.1 IEA EBC Annex 81: Data-Driven Smart Buildings

The EBC Annex 81 aim is to increase access to low-cost high-quality data from buildings and support the development of data-driven software 'Applications' and analytics, that provide real time building optimization and decision support for building facilities managers.

In order to achieve the overarching Annex aim, the Annex has a number of specific objectives relating to the subcomponents of (i) data-collection, (ii) digital characterisation of buildings, (iii) coding of knowledge into smart "Applications", and (iv) supporting the utilisation of data-driven products and services. These additional objectives are

- Provide the knowledge, standards, protocols and procedures for low-cost high-quality data capture, sharing and utilization in buildings.
- Develop a Building Emulator platform that enables testing, development and assessment of the impact of alternative building HVAC control strategies in a digital environment.
- Develop building energy efficiency (and related) software 'Applications' that can be used and ideally commercialized for reducing energy consumption in buildings.
- Drive adoption of Annex results through case studies, business model innovation and results dissemination.

## 5.2 IEA EBC Annex 84: Demand Response of Buildings in Thermal Networks

It has been proven that buildings can offer flexibility to the power grid by smart control of heat pumps, EVs or white goods. Yet, in a significant share of households the heating and/or cooling demands are satisfied by district thermal grids, and if present, the thermal infrastructure and its potential for flexible and sustainable heating and cooling supply is considered as the strategic component of roadmap towards low-carbon future and gas-free neighbourhoods. The operational challenges of heating and cooling networks (DHC Nets) differ from the power grids. The DHC Nets need to address the issues like faulty operation of heating/cooling technology in buildings, incorrect use of installations by the end-users (e.g. high return temperatures from critical customers, etc.). Therefore, there is a need to investigate how the active management of thermal demands in buildings can enhance operation of thermal grids and thus reduce the need for currently fossil-fuel-based and/or costly peak production, reduce the thermal losses and enhance the capacity of existing networks. Moreover, it is the perfect time to detect transition barriers for related policy and business development, and to identify new opportunities for buildings and end-users to become an active element of the operation and control scheme of thermal networks. Accordingly, it is also the perfect time to test and demonstrate how such new approaches and technological solutions can be implemented in real life environments.

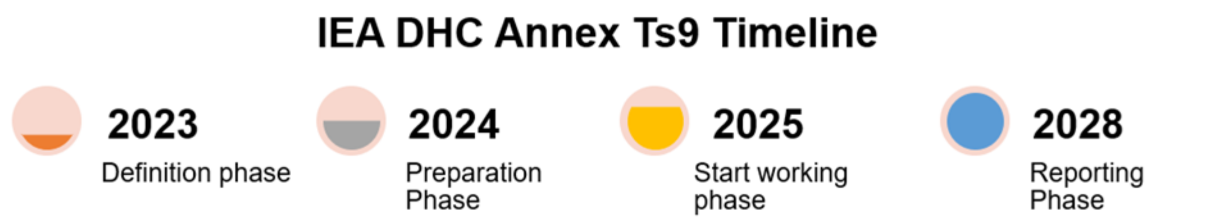
The deliverables will include technical reports, summary of best practice solutions, design guidelines and recommendations and methodologies for big-data utilisation.

### 5.3 IEA HPT Annex XX (DO we have more? Can we add CITIES?)

To be discussed during the preparation phase meeting in May 2024

# 6 Time Schedule

The IEA Annex TS9 will be led by Denmark and Germany. The operating agents will be Michele Tunzi (DTU) and Dietrich Schmidt (Fraunhofer Institute). We held the first definition meeting for the IEA Annex TS9 last 22nd November 2023 in Berlin, where the entire international Team started collecting the interest and commitment as well as details about project contents, organisation, and activities. The next meeting will be help in Belgium next 27-28 May 2024 in Antwerp. The project timeline is graphically presented in the following figure.




| 2023 | | 2024 | | 2025 | | 2026 | | 2027 | | 2028 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | x | x | x | x | x | x | x | x | x | x | |
| **Definition** | | **Pre** | **Working Phase** | | | | | | **Reporting** | | |

**Figure 3: Time schedule of the DHC Annex TS9 and indicated project meetings**

May 2023: possible approval to start the definition phase (DHC ExCo Meeting)

Sept. 2023: start definition phase

Nov. 2023: definition phase WS in Berlin (Nov. 23, 2023)

Nov. 2023: possible approval to start preparation phase (ExCo meeting)

May. 2024: start preparation phase (1/2 year)

Sept 2024: start working phase (annex text available)

Nov. 2027: start reporting phase

June 2028: official end of the Annex

# 7 Funding

Participation in this IEA DHC task shared annex requires a minimum effort of 12 person-months per country. Each participant's country is required to take part in at least one of the subtasks and it is recommended that all participants take part in Subtask E. Participation may partly involve funding allocated to a national activity, which falls substantially within the scope of work to be performed under this annex. Aside from providing the resources required for performing the work of the subtasks in which they are involved, all participants are required to provide the resources necessary for activities that are specifically collaborative in nature and are not meant to be part of a national program; for example, establishing common monitoring procedures, preparation for and participation in annex meetings, co-ordination with subtask participants, and contribution to documentation and information dissemination.

The meetings shall be hosted in turn by the various participants. The costs of organising and hosting meetings shall be borne by the host participant. Each participant will bear his/her own travel costs to the expert meetings.

The cost of publishing the reports and summary assessments shall be borne by the Operating Agent.

# 8 Participants

The DHC member countries currently participating in the Annex TS9 activities are:

- Austria, Belgium, Canada, China, Denmark, France, Germany, Norway, South Korea, the Netherlands, Sweden and the United Kingdom.

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