Project 65

Heat pumps in a circular economy

Task 2 Report

Operating Agent
Jakob Thomsen,
Danish Technological Institute

October 2025
Report no. HPT- AN65-3

Published by Heat Pump Centre
c/o RISE – Research Institutes of Sweden
Box 857, SE-501 15 Borås
Sweden
Phone +46 10 16 53 42
Website https://heatpumpingtechnologies.org

Production Heat Pump Centre, Borås, Sweden

ISBN 978-91-90036-72-3
Report DOI: 10.23697/bv3k-rx94
Report No. HPT-AN65-3

Preface

This project was carried out within the Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP), which is a Technology Collaboration Programme within the International Energy Agency, IEA.

The IEA

The IEA was established in 1974 within the framework of the Organization for Economic Cooperation and Development (OECD) to implement an International Energy Programme. A basic aim of the IEA is to foster cooperation among the IEA participating countries to increase energy security through energy conservation, development of alternative energy sources, new energy technology and research and development (R&D). This is achieved, in part, through a programme of energy technology and R&D collaboration, currently within the framework of nearly 40 Technology Collaboration Programmes.

The Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP)

The Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP) forms the legal basis for the implementing agreement for a programme of research, development, demonstration and promotion of heat pumping technologies. Signatories of the TCP are either governments or organizations designated by their respective governments to conduct programmes in the field of energy conservation.

Under the TCP, collaborative tasks, or “Annexes”, in the field of heat pumps are undertaken. These tasks are conducted on a cost-sharing and/or task-sharing basis by the participating countries. An Annex is in general coordinated by one country which acts as the Operating Agent (manager). Annexes have specific topics and work plans and operate for a specified period, usually several years. The objectives vary from information exchange to the development and implementation of technology. This report presents the results of one Annex. The Programme is governed by an Executive Committee, which monitors existing projects and identifies new areas where collaborative effort may be beneficial.

Disclaimer

The HPT TCP is part of a network of autonomous collaborative partnerships focused on a wide range of energy technologies known as Technology Collaboration Programmes or TCPs. The TCPs are organised under the auspices of the International Energy Agency (IEA), but the TCPs are functionally and legally autonomous. Views, findings and publications of the HPT TCP do not necessarily represent the views or policies of the IEA Secretariat or its individual member countries.

The Heat Pump Centre

A central role within the HPT TCP is played by the Heat Pump Centre (HPC).

Consistent with the overall objective of the HPT TCP, the HPC seeks to accelerate the implementation of heat pump technologies and thereby optimise the use of energy resources for the benefit of the environment. This is achieved by offering a worldwide information service to support all those who can play a part in the implementation of heat pumping technology including researchers, engineers, manufacturers, installers, equipment users, and energy policy makers in utilities, government offices and other organisations. Activities of the HPC include the production of a Magazine with an additional newsletter 3 times per year, the HPT TCP webpage, the organization of workshops, an inquiry service and a promotion programme. The HPC also publishes selected results from other Annexes, and this publication is one result of this activity.

For further information about the Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP) and for inquiries on heat pump issues in general contact the Heat Pump Centre at the following address:

Heat Pump Centre
c/o RISE - Research Institutes of Sweden
Box 857, SE-501 15 BORÅS, Sweden
Phone: +46 10 516 53 42
Website: https://heatpumpingtechnologies.org

Operating Agent

Jakob Thomsen
Product Manager, Danish Technological Institute
jath@dti.dk
+45 72 20 15 63

Participating countries

Country	National contact	Date of joining the annex
Denmark	Jakob Thomsen	1/1-2024
Germany	Dr. Karl-Anders Weiß	1/1-2024
Italy	Marco Dall'Ombra	31/1-2024
France	Julien Ballou	03/09-2025

Participants and contributors

Name	Company	Role/Title	Country	Contact information
Jakob Thomsen	Danish Technological Institute	Product Manager	Denmark	jath@dti.dk +45 72 20 15 63
Troels Stevns Pedersen	Danish Technological Institute	Consultant	Denmark	tsp@dti.dk
Dr. Karl-Anders Weiß	Fraunhofer ISE	Business Developer Service Life and Sustainability	Germany	Karl-Anders.Weiss@ise.fraunhofer.de
Marie Fischer	Fraunhofer ISE	Engineer	Germany	marie.fischer@ise.fraunhofer.de
Marco Dall'Ombra	Assoclima	Assoclima Representative	Italy	dallombra@assoclima.it
Dr.-Ing. Christian Vering	RWTH Aachen University	Chief Engineer, Team Leader Refrigerant Cycles	Germany	cvering@eonerc.rwth-aachen.de
Univ.-Prof. Dr.-Ing. Dirk Müller	RWTH Aachen University	Professor	Germany	dmueller@eonerc.rwth-aachen.de
Gitte Tang Kristensen	Danfoss	Senior Manager, Circularity and Product Compliance	Denmark	gtang@danfoss.com
Yana Petkova-Olsson	Nibe	Knowledge Expert Life Cycle Assessments	Sweden	Yana.Petkova-Olsson@nibe.se
Per Thomsen	Vølund Varmeteknik	Technical and Service Manager,	Denmark	per.thomsen@volundvt.dk
Danielle Camara	Grundfos	Circularity Specialist	Denmark	dasilva@grundfos.com
Valeriy Matveev	UGent	Predoctoral Researcher	Belgium	valeriy.matveev@ugent.be
Jahanzeb Tariq	Carrier Residential & Light Commercial EMEA	Global Manager Sustainable Products and Circularity	Germany	trqj@viessmann.com

Sara Billo	Alfa Laval	BFB QHSE & Sustainability Manager	Italy	sara.billo@alfalaval.com
Benedetta Copertaro	Alfa Laval	BB LSS Sustainability Project Manager BU BFB	Italy	Benedetta.Copertaro@alfalaval.com
Julien Ballou	CETIAT	Project Manager	France	julien.ballou@cetiat.fr
Dr. Agathoklis Krimpenis	Hellenic Mediterranean University	Associate Professor	Greece	akrimpenis@hmu.gr
Dr. Maria Koukou	National and Kapodistrian University of Athens	Associate Professor	Greece	mkoukou@agro.uoa.gr
Susanna Cohen	Deep Blue	Dissemination, Visual & Graphic Design Consultant	Italy	susanna.cohen@dblue.it
Pascal Köhler	ebm-papst neo GmbH & Co. KG	Director Business Innovation & Marketing,	Germany	pascal.koehler@epneo.com

Foreword

The shift towards a circular economy is influencing many sectors, including the heat pump industry. This report, developed as part of the International Energy Agency's Technology Collaboration Programme on Heat Pumping Technologies (HPT), examines how circular economy principles affect domestic heat pumps.

This Task 2 Report aims to provide an overview and a common understanding among the participants in the project and stakeholders outside the project of various aspects related to the transition to a circular economy within the heat pump industry. By focusing on air-to-air, air-to-water, and ground source heat pumps, we explore ways to incorporate these principles into the lifecycle of heat pump systems.

I would like to thank all participants and contributors for their hard work and expertise. Your collaboration has been essential in advancing our understanding of sustainable practices in the heat pump sector.

We hope this report will serve as a useful resource for policymakers, manufacturers, and stakeholders interested in promoting sustainability within the heat pump industry.

Jakob Thomsen - Project Leader of Project 65 of the IEA Technology Collaboration Programme on Heat Pumping Technologies.

Abstract

This Task 2 Report, developed under the International Energy Agency's Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP), builds on foundational work to investigate the state-of-the-art in the practical application of circular economy principles within the domestic heat pump sector. Focused on air-to-air, air-to-water, and ground source heat pumps, the report examines real-world strategies, projects, and business models that are currently advancing circularity. The study provides an overview of existing take-back strategies, from comprehensive national systems to targeted, company-led initiatives, and analyzes their effectiveness in recovering value from end-of-life products.

Case studies and project reviews from across Europe offer practical insights into the implementation of circularity. The report details the critical role of digitalization, particularly through tools like the Digital Product Passport, in achieving material transparency and enabling data-driven decisions that support repair, refurbishment, and recycling. Furthermore, it explores emerging circular business models, such as "Heat-as-a-Service," which shift the focus from product ownership to lifetime value and facilitate systematic product reuse.

The findings demonstrate that the heat pump sector is actively, though gradually, transitioning towards a circular economy. Key learnings highlight that progress is being driven by a combination of national policies, manufacturer-led pilots, strong value chain collaborations, and innovative business models. By showcasing tangible solutions, this report provides a practical foundation to guide policymakers, manufacturers, and stakeholders in accelerating the adoption of sustainable practices in the heat pump industry.

1. Executive Summary

This Task 2 Report builds upon the foundational work of the Task 1 report, shifting the focus from theoretical frameworks to the state-of-the-art in the practical application of circular economy principles in the domestic heat pump sector. Developed under the International Energy Agency's Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP), this report examines real-world strategies, projects, and business models that are advancing circularity for air-to-air, air-to-water, and ground source heat pumps.

The report is structured around four key tasks:

- **Task 2.1 - Take-back strategies for heat pumps and their parts:** This task investigates existing and emerging systems for collecting end-of-life heat pumps and their components, analyzing models from national initiatives to company-led pilots.
- **Task 2.2 - Research projects that focus on circularity and sustainability:** An overview of current research initiatives that are actively exploring circular design, material transparency, and sustainable practices for the next generation of heat pumps.
- **Task 2.3 - Status on circular economy transition and updates from authorities:** This section provides an update on the circular economy transition at both the European and national levels, including the latest regulatory developments that impact heat pump product design.
- **Task 2.4 - Current business models for circular economy practices:** The analysis focuses on innovative business models, such as "Heat-as-a-Service," that aim to decouple revenue from resource consumption and extend the functional life of heat pumps.

Key findings from the report include:

- A variety of take-back models are emerging, but no single approach dominates. These range from the comprehensive, fee-based national system in Switzerland to targeted, company-led initiatives like the Grundfos-NIBE collaboration on remanufactured components, which prove the technical and business viability of component reuse.
- Addressing informal or untracked waste streams is a major challenge. The case of Erion in Italy highlights how informal scrap markets divert valuable materials from official recycling channels, underscoring the need for structured, incentivized collection programs like "Exceed Clima" to engage installers and ensure proper handling.
- Digitalization is a critical enabler for circularity. The CE-RISE project, featuring Viessmann's heat pump case study, demonstrates that Digital Product Passports (DPPs) are essential for achieving material transparency, tracing components, and making data-driven decisions that support repair, refurbishment, and recycling.
- Circular business models are moving from concept to reality, with "Heat-as-a-Service" (HaaS) being a prominent example. The model offered by Vølund Varmeteknik in Denmark shows that by retaining ownership, companies can manage the entire product lifecycle, enabling systematic maintenance, refurbishment, and redeployment of heat pumps.
- Cross-value chain collaboration is fundamental to the success of any circular initiative. The success of the presented cases consistently relies on strong partnerships between manufacturers, component suppliers, installers, service providers, and recycling organizations.

In conclusion, this report demonstrates that the heat pump sector is actively, though gradually, transitioning towards a circular economy. The practical examples and case studies presented serve as a valuable foundation, showcasing tangible solutions and providing key learnings.

2. Background

Background
The report for Task 2 is part of Project 65 under the International Energy Agency's Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP). Task 2 builds upon the findings gathered in Task 1, which provided an initial exploration of circular economy principles in heat pump systems. Expanding on that foundation, this report dives deeper into specific strategies, research initiatives, and business models that promote circularity in domestic heat pumps.

The Task 2 Report is focused on defining the state-of-the-art in circular economy strategies. Circular economy principles and strategies, which emphasize resource efficiency, waste reduction, and the reuse and recycling of materials, are increasingly being adopted across the globe. Understanding these strategies and their implementation is essential for advancing sustainability.

One valuable resource for exploring circular economy strategies worldwide is the Circular Economy Earth platform [1]. This platform provides an interactive map that shows various circular economy initiatives and strategies implemented by different countries and regions. By offering a global perspective, the platform enables users to explore how diverse nations approach circular economy practices, highlighting regional trends, innovative solutions, and policy approaches. Figure 1 is a screenshot of the global map of circular economy strategies, which highlights the diversity and scope of circular economy initiatives around the world: Circular economy strategies are found across the world and in both developed and developing economies. The website also includes a database with references to the type of policy, the policy name, the lead organization, the start and end year, and links to detailed descriptions. The insights derived from this resource can help build an understanding of the current landscape of circular economy practices, serving as a valuable reference for identifying opportunities, challenges, and best practices in fostering sustainability on a global scale.

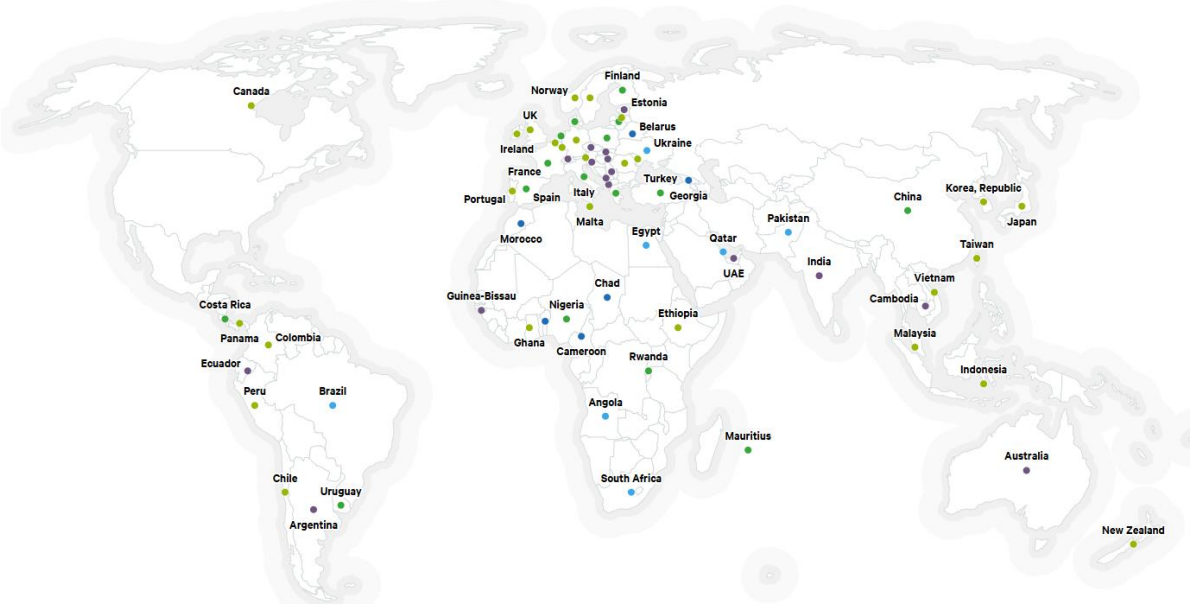


Figure 1: Screenshot from 2025 from circulareconomy.earth [1].

While circular economy strategies are being implemented in various countries, this approach is still relatively new for heat pump companies. In this report, we examine ongoing activities related to the circular economy within the heat pump sector. This will be combined with some general guidelines and theoretical frameworks to support companies that wish to explore this topic further.

3. Structure of this document

The document is structured to align with the legal text for Project 65, focusing on heat pumps in a circular economy. It includes sections dedicated to each specific subtask described in the legal text, providing a comprehensive overview. The subtasks are:

- Task 2.1 - National take-back strategies for heat pumps and their parts.
- Task 2.2 - Research projects that focus on circularity and sustainability in domestic heat pumps.
- Task 2.3 - Status on circular economy transition and latest updates from authorities on circular economy and material efficiency impacting heat pump product design.
- Task 2.4 - Current business models for circular economy practices related to heat pumps in participating countries.

The report will include detailed findings from our research and incorporate perspectives from industry stakeholders to reflect the different perspectives in the project group. General theory and frameworks related to circular economy aspects have been included in the introduction section of the tasks to provide a general introduction to the topic and frameworks for the reader to use if similar activities are considered.

4. Task 2.1 - Take-back strategies for heat pumps and their parts

Take-back systems can be a key part of a company's transition to circular economy strategies as these systems can close the loop on the products that the company produces. These systems can play a crucial role in reducing waste, conserving resources, and promoting the reuse of valuable materials and components. By enabling the recovery and recirculation of heat pump parts, take-back systems help companies move towards more sustainable practices.

Take-back systems can be an intangible concept to grasp, but Uhrenholt et al. have provided a definition that states: *"A take-back system is as an operational set of processes including the collection of end-of-life (EoL) products, transportation, sorting and disassembly, requalification, and re-engagement of the recovered material, components or products in the forward supply chain"* [2].

Take-back systems are also referred to in literature as "reverse logistics". The study by Mallick et al. serves as a comprehensive literature review, exploring what research has been conducted in this area by systematically reviewing 116 scholarly articles published between 2011 and 2021 [3]. In their analysis, Mallick et al. identified a range of drivers for implementing reverse logistics, as well as key performance indicators (KPIs) relevant across different industries. They also developed a conceptual framework and tool to support companies in designing and implementing reverse logistics systems for circular economy practices. This framework is shown in Figure 2.

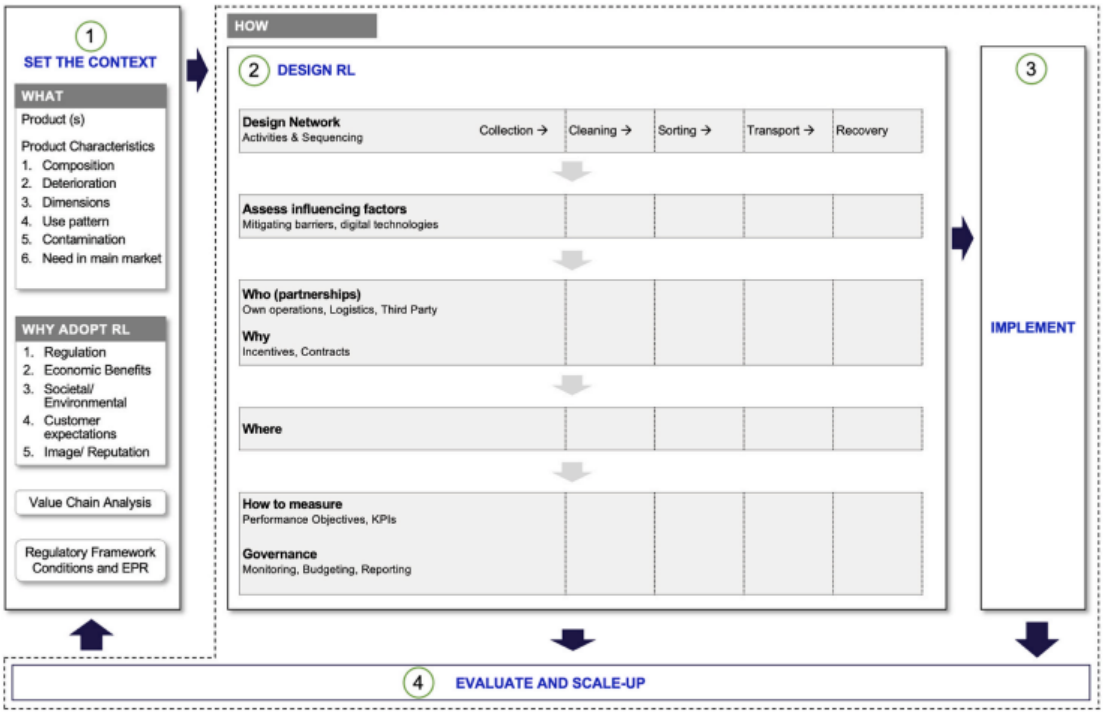


Figure 2: Conceptual framework for take-back systems developed by Mallick et al. [4].

While the definition above provides a theoretical framework for understanding take-back systems, practical experience shows that implementing these systems in real-world contexts often involves additional complexities and challenges. To bridge the gap between theory and practice, it is valuable to consider insights from practitioners who have worked directly with developing and operating take-back strategies. Damborg and Jørgensen have compiled their learnings in a "Practitioner's guide to take-back systems" based on lessons learned from companies in various industries and highlights several key challenges and recommendations that are directly relevant for the heat pump sector [5]. An extract of the learnings is described in the following section.

1. **Where do we begin?**
   Many companies struggle with how to take the first steps in setting up a take-back system, and Damborg and Jørgensen emphasize the importance of avoiding rigid assumptions about where products end up or how they might be returned [5]. Rather than designing an ideal system on paper, companies are encouraged to “get their hands dirty” by experimenting with existing return flows, such as warranty claims, service returns, or naturally occurring product recalls. By starting small and learning from actual cases, organizations can identify unforeseen barriers and opportunities, reduce uncertainty, and develop scalable solutions based on real experience rather than speculation.

2. **How do we find our products?**
   Locating end-of-life products is often more difficult than anticipated and to support this process, Damborg and Jørgensen identified four typical “ecosystem archetypes”, see Figure 3, that describe how products move through the value chain: direct sales to large customers, products as components in larger systems, sales via distributors, and sales through retailers [5]. Each archetype presents its own set of challenges and requires tailored strategies and incentives to encourage returns. For instance, in direct sales, it may be easier to negotiate take-back agreements with known customers, while in retail scenarios, the manufacturer may have little visibility and must collaborate with shops or service organizations to reach end-users. Damborg and Jørgensen underscore the importance of mapping the value chain, identifying all actors who handle the product, and understanding their motivations for participating in a take-back system.

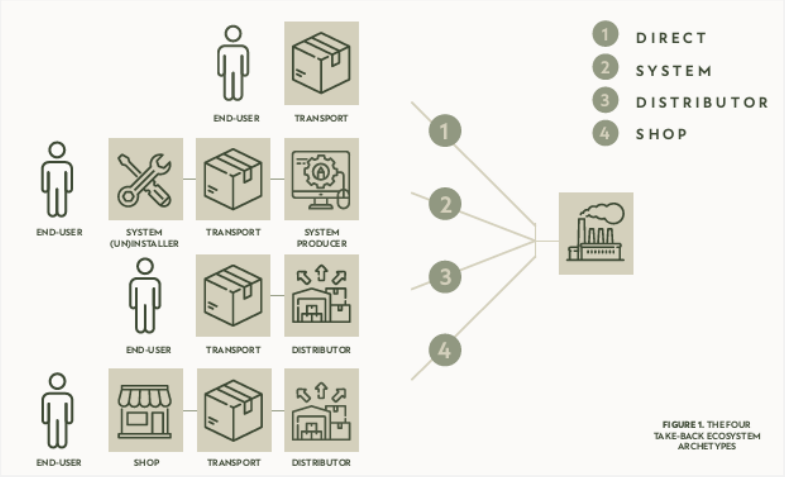


Figure 3: The four take-back ecosystems archetypes [5].

3. **What do we do with the products?**
   Once end-of-life products are collected, companies face the decision of what to do with them. Damborg and Jørgensen recommend setting a clear product recovery goal from the outset: is the priority to reuse the product as-is, recover and reuse specific components, or recycle the materials? Each option has different requirements for logistics, partners, and processes. For example, direct reuse may require inspection and light refurbishment, while component reuse involves more disassembly and testing. Material recycling often depends on external partners with specialized capabilities. Damborg and Jørgensen stress that the flow of information is as important as the flow of products - data about product type, condition, and return reason must accompany each item to maximize value creation and support efficient decision-making. Integrating product and data flows also strengthens reporting on environmental and resource efficiency metrics.

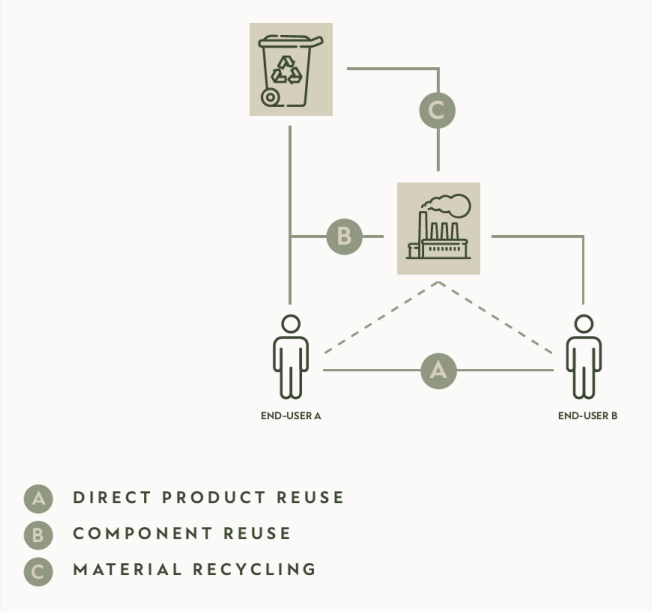


Figure 4: Three basic goals of the take-back system [5].

4. **How do we make a business case?**
   Developing a solid business case for a take-back system involves understanding not only the direct financial costs and benefits, but also broader value factors. Damborg and Jørgensen explain that take-back systems can generate value by providing access to critical raw materials, reducing supply chain risks, strengthening compliance with environmental regulations, and differentiating a company in the market. In addition, take-back systems can improve a company's carbon footprint by capturing and recycling materials, and thereby supporting sustainability goals. To build a robust business case, the guide recommends mapping all activities involved - such as collection, transport, sorting, and processing - and identifying cost drivers and potential sources of value for both the manufacturer and the end-user. Collaboration with external partners can also reveal new opportunities and help distribute costs and benefits more fairly.

The practitioner's guide developed by Damborg and Jørgensen makes it clear that successful take-back systems are rarely created by following a one-size-fits-all template. Instead, they require ongoing experimentation, strong partnerships across the value chain, and a willingness to adapt based on experience and feedback.

Beyond the practical insights described above, take-back systems offer a range of environmental and economic benefits for companies in the heat pump industry. By recovering and reusing materials, companies can reduce both costs and resource consumption, while the refurbishment and resale of components may open up new revenue streams. These practices support overall sustainability goals and contribute to greater economic resilience. Despite these advantages, implementing take-back systems remains challenging. Developing efficient logistics networks for collecting and processing returned products is often complex, and companies must also ensure compliance with evolving regulations and maintain the quality and safety of reused components. Addressing these challenges requires careful planning, innovation, and continuous improvement.

In addition to practitioner experience, recent research from the CIRCit project ("Closing the Loop for a Circular Economy") provides structured guidance on developing and evaluating take-back systems as a foundation for circularity. According to CIRCit Workbook 5, take-back systems are essential for "closing the loop", enabling companies to recover products and materials at end-of-use or end-of-life and select the most suitable recirculation strategy. The CIRCit approach highlights that effective take-back systems should support a range of recovery options, not just one. After collecting products, companies need to determine whether an item is best suited for reuse, refurbishment, remanufacturing, recycling, or other forms of value recovery. The workbook identifies nine main recirculation pathways - ranging

from direct reuse and repair to recycling and recovery - each with different requirements for sorting, processing, and value retention.

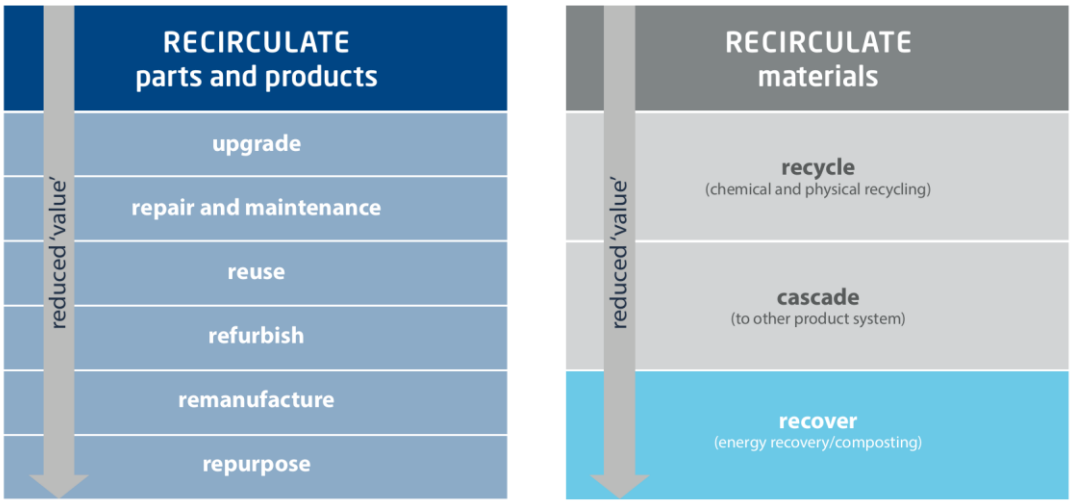


Figure 5: Recirculate; Parts & products, and materials.

The workbook also underlines the importance of integrating product and data flows. Information about product type, condition, and reason for return should accompany each item to support efficient sorting and decision-making. Mapping the value chain and identifying all actors involved in product handling are also crucial for designing practical and robust take-back systems.

By applying these structured criteria, companies can move beyond ad-hoc recovery efforts and develop take-back systems that maximize value, ensure compliance, and support circular economy objectives. For detailed tools and step-by-step guidance, see CIRCit Workbook 5: Closing the Loop for a Circular Economy.

The following subsections will delve into take-back systems for the heat pump industry identified in HPT Project 65 and explore the opportunities they present as well as the challenges they pose. Lastly, a section summarizes the learnings from the theory and the practical systems described.

4.1. Swiss take-back system on product level

To increase the use of heat pumps in Switzerland, while securing an environmentally responsible disposal, Switzerland has introduced an initiative to develop a sustainable and cost-effective solution to minimize the environmental impact through proper disposal. Several organizations are involved in this initiative, including SENS eRecycling, which is responsible for recycling management, Gebäude Klima Schweiz (GKS), which is committed to building technology, and the Swiss Heat Pump Association (FWS), which acts as a specialist organization for heat pump technology [6].

A so-called advance or prepaid recycling fee (*vorgezogener Recyclingbedarf,* vRb) has been implemented to finance the costs for the collection, transportation and recycling of heat pumps, as well as the monitoring of recycling companies [7], [8]. This corresponds to a fixed amount that consumers pay directly to the installer or manufacturer/importer when purchasing heat pumps. Manufacturers and importers report their sales to SENS eRecycling at regular intervals and pay the proceeds from the vRb into the fund provided for this purpose to the privately organized, non-profit foundation. The fund works on a pay-as-you-go basis [6].

The manufacturers and importers who have joined the initiative currently cover a market volume of between 70 and 80% of the Swiss market for heat pumps [6]. Many manufacturers and importers see this new industry solution as a way of fulfilling their obligation to take back used heat pumps in an efficient and uncomplicated manner.
The collection takes place through the collection of old heat pumps by SENS eRecycling, with the additional option of handing them in free of charge at over 750 SENS collection points [6].

Disposed appliances are transported efficiently to the recycling plants using a structured logistics system to minimize emissions. The heat pumps that are disposed of via the new industry solution vary in size. Their maximum output is 350 kW, or 20 kW in the case of water heater heat pumps [9]. Recycling is carried out by certified companies with SENS licenses, which ensures environmentally responsible processing and reintegration into the raw materials cycle [6], [10].

SENS eRecycling carries out regular inspections to monitor the recycling companies and ensure compliance with environmental and occupational health and safety standards. Only companies with the necessary permits are allowed to process the appliances, and the quality of the recycling processes is guaranteed through regular audits [6]. Transparent reporting is also carried out, which includes documentation of the disposal and recycling processes for all parties involved.

Environmental protection is ensured by properly removing environmentally harmful refrigerants before recycling [6]. This helps to prevent the release of harmful gases into the atmosphere. Resource extraction involves recycling valuable materials such as aluminum, iron, copper, and plastics, which supports the promotion of a circular economy approach. Sustainability is promoted by strengthening environmental responsibility within the industry, while the ecological footprint is reduced through efficient disposal. Efficiency is reflected in optimized take-back processes for manufacturers and importers as well as in the minimization of administrative effort through a central organization. Broad support results from the voluntary participation of manufacturers and importers, which promotes cooperation and has a positive impact on corporate image through environmentally friendly practices.

4.2. Danfoss take-back system on radiator thermostats

Danfoss is a participant in HPT Project 65 and serves as a major supplier of important components for heat pumps. The company also has experience in developing and implementing take-back systems for other product groups. These experiences provide valuable knowledge that can support the development of circular initiatives for heat pump components. The following section presents Danfoss's concrete experiences from a pilot take-back project for radiator thermostats. Afterwards, these experiences are related to opportunities and challenges for circular solutions for heat pump components, based on Danfoss's expertise and role in the industry.

Danfoss' main aim of the pilot take-back project is to demonstrate resource efficiency and support circular business models by enabling the recirculation of materials, particularly plastics. The project involves collaboration between wholesalers, installers, and Danfoss, and has already demonstrated environmental benefits such as the potential of reducing the carbon footprint of the thermostats by up to 23% through plastic recycling.

This take-back initiative, while not directly targeting heat pumps, provides valuable insights applicable to circular solutions for heat pump components. The Danfoss project highlights opportunities and challenges in circular initiatives, many of which are transferable to other product groups, including key components of heat pumps.

Key learnings and relevance for heat pump components:

- Logistics and collaboration**:** An effective take-back system relies on well-organized logistics and strong cooperation between different actors in the value chain. This is also essential for heat pumps, where components are distributed and installed through multiple channels. See Figure 6.
- Material recycling**:** Experience with disassembly, sorting and recycling in radiator thermostats can inspire similar approaches for heat pump components, where material recycling may be technically or economically challenging.
- Regulatory issues**:** Handling and transporting end-of-life products across borders presents regulatory challenges, which are also relevant for the heat pump sector.
- Scalability**:** Danfoss is continuously evaluating how the pilot project can be expanded to include more types of components and new markets. Similar considerations apply to the heat pump sector, where product range and market size can vary.

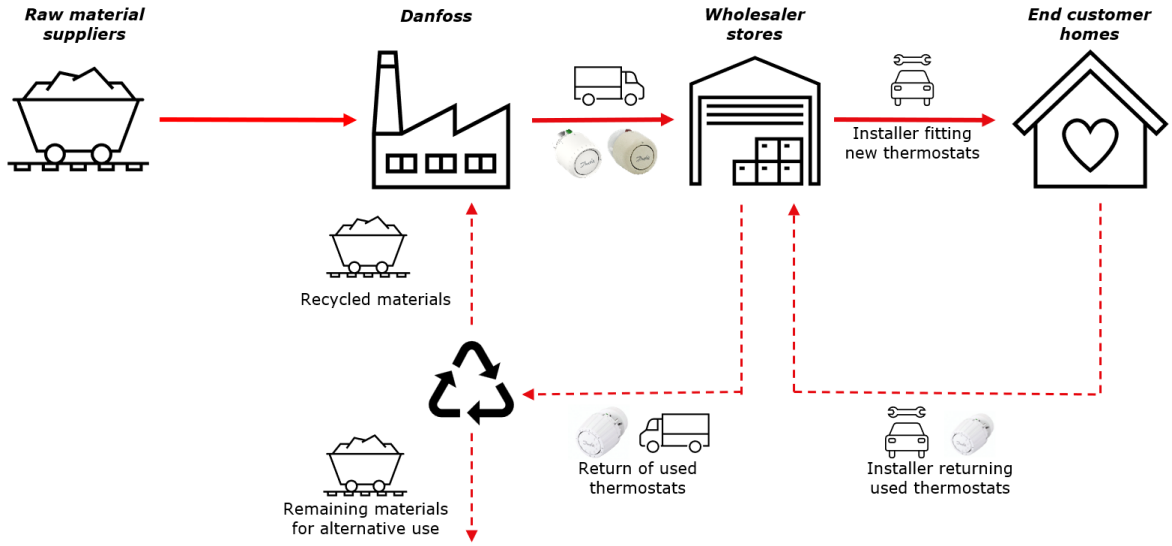


Figure 6: Danfoss radiator thermostat take-back system. Source: Danfoss.

Reflections

The Danfoss take-back project for radiator thermostats highlights both opportunities and barriers that are likely to be relevant for circular initiatives targeting heat pumps and their components. In particular, models for collaboration, logistics solutions, and the use of circularity assessment tools can be transferred. At the same time, the complexity may be greater for products that are integrated into larger technical systems, such as heat pumps. The case is elaborated in further detail in Appendix 1.

4.3. Findings from Grundfos and circulation pumps

This section presents a real-world example of a take-back strategy directly relevant to the circular economy transition in the heating sector. Grundfos, a global leader in pump technology, has developed a take-back and remanufacturing system for small circulator pumps, including components widely used in domestic heat pump systems. Examining their approach provides insight into both the opportunities and the challenges of implementing circularity with key components in heating and cooling technology.

Grundfos established its take-back system in 2021, focusing initially on domestic building service pumps. The company partners with installers and wholesalers to collect used circulation pumps from end users. Installers return the old pumps to wholesale collection points, from where they are transported to Grundfos's central facility for disassembly and further processing. In the disassembly facility, pumps are carefully taken apart. Components with potential for remanufacturing - such as permanent magnet rotors and cast-iron pump housings - are separated and stored. Components that cannot be reused are sent to specialized recycling partners. By remanufacturing robust components, Grundfos aims to conserve raw materials, reduce environmental impact, and support the move towards a circular business model. A key part of the system is social inclusion: the disassembly line employs workers with disabilities, providing flexible working conditions and additional social value. The take-back system is illustrated in Figure 7.

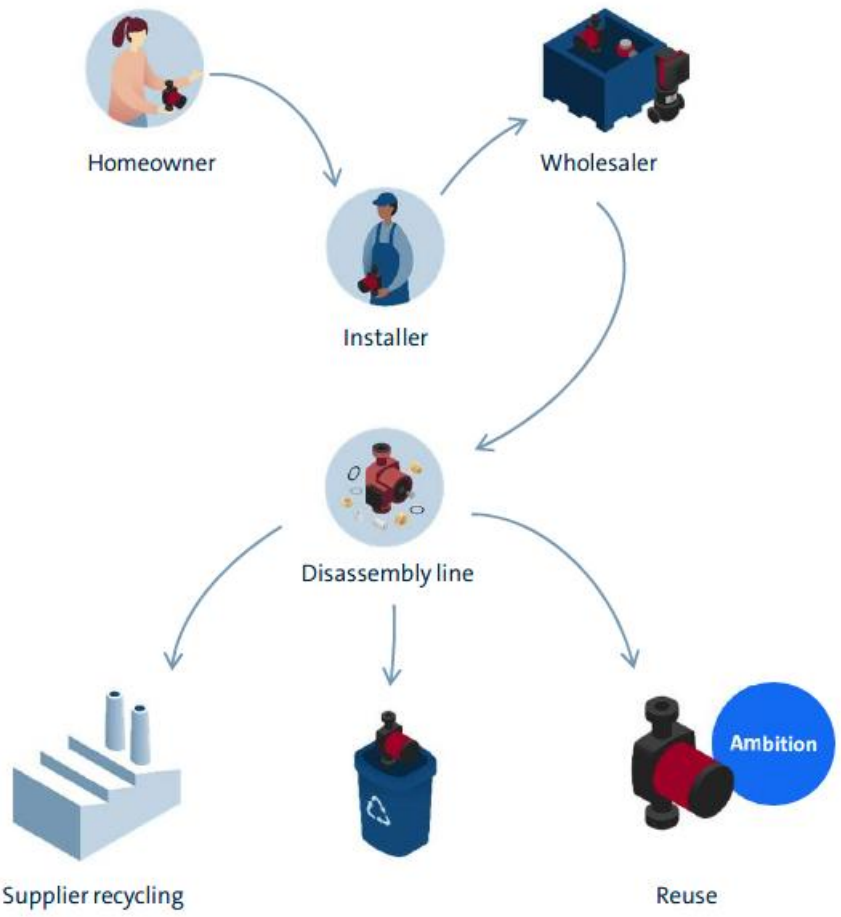


Figure 7: Schematic of Grundfos take-back system. Source: Grundfos.

While the system has succeeded in recovering substantial volumes of used pumps, several challenges persist. These include integrating the take-back process into company-wide systems, ensuring traceability and quality of returned parts, and scaling the process to achieve economic viability. Grundfos reports that environmental benefits are clear - remanufactured rotors and housings can save up to 50% of CO_2 emissions versus new production - but highlights that higher return volumes are needed for the business case to mature.

In 2022, Grundfos provided NIBE with 10,000 circulator pumps, all of which were fitted with remanufactured reused rotors. This collaboration marked an important step in demonstrating that components designed with durable materials, such as permanent magnet rotors, can be successfully remanufactured and reused in new products through strong partnerships across the value chain.

For NIBE, the motivation for participating in this pilot project was closely linked to both environmental and business goals. As operational carbon emissions from heat pumps decrease due to a cleaner electricity mix, addressing the embodied emissions from manufacturing and materials become increasingly important. Sourcing remanufactured components helps NIBE reduce the CO_2 footprint of its products.

NIBE recognizes that robust product design and durable materials are essential for enabling effective circular strategies, even many years into a product's lifecycle. The company also stresses the importance of reliable material data and traceability to meet growing customer and regulatory demands for information about environmental impacts. By adopting circular approaches and integrating remanufactured components, NIBE aims to remain at the forefront of industry trends and be prepared for the increasing market focus on lifecycle emissions and sustainability.

Through this collaboration, both Grundfos and NIBE gained practical experience in integrating take-back, remanufacturing, and reuse processes within the supply chains for domestic heating technology. The case highlights the value of cross-company cooperation and the shared commitment to advancing circular economy practices in the heat pump sector.

4.4. Erion – Italian waste handler with projects into take-back systems

This case study explores how Erion, an Italian organization, manages the collection and recycling of waste electrical and electronic equipment (WEEE), including heat pumps. It outlines the processes for gathering, treating, and recovering valuable materials from end-of-life products within Italy's regulatory framework. The example highlights the practical challenges involved in ensuring proper recycling - such as regulatory compliance and competition from informal scrap markets - while also detailing the opportunities and solutions that support circular practices in the heat pump industry.

Like other Electrical and Electronic Equipment (EEE), heat pumps have a useful life that determines their technological obsolescence. When they reach the end of their life, they are categorized as Waste Electrical and Electronic Equipment (WEEE), falling within the scope of Directive 2012/19/EU and Legislative Decree 49/2014 since 2018. This regulation aims to contribute to the management of WEEE to promote its recovery and correct management, redefining the obligations of EEE producers. According to data from the WEEE Coordination Center, in 2024 the Collective Systems, adhering to the Coordination Center, managed 358,138 tons of WEEE in Italy. Specifically, for Group R1 - Temperature and fluid exchange equipment - 104,407 tons of domestic waste were managed, with an increase of 3.3% compared to 2023 data.

In 2024, Erion managed 76,925 tons of R1 from which it was possible to obtain the following Secondary Raw Materials: 2,231 tons of aluminum, 538 tons of other metals, 1,462 tons of copper, and 45,615 tons of iron.

In addition to Secondary Raw Materials, thanks to the activities performed in the treatment plants, it was also possible to recover the refrigerant contained in the WEEE collected, a portion of which has been sent to the reclaiming process held by specialized companies.

In a WEEE plant designed to manage a significant amount of air conditioners, we can assume that it has the potential to accept from 500 and 1,000 tons of end of life Domestic and Professional products. Taking into account that many air conditioners arrive empty at the plant, we can estimate to be able to collect around 10 tons of refrigerant annually, half of which (5 tons) could be reclaimed to become "virgin refrigerant". The most common types of gases recovered are: R410A, R407C, R134A, and R32.

Product flow

The heat pump industry is characterized by a complex supply chain, where multiple subjects interact with each other and among which different flows of WEEE occur. The product's flow can be divided between the supply chain flow and the end-of-life flow. In the first case, Figure 8, products flow from the manufacturer to the end user (Domestic or Professional). In the second case, Figure 9, products flow from the place where they were installed to the collection place and the treatment plants where they will be dismantled and recycled as much as possible.

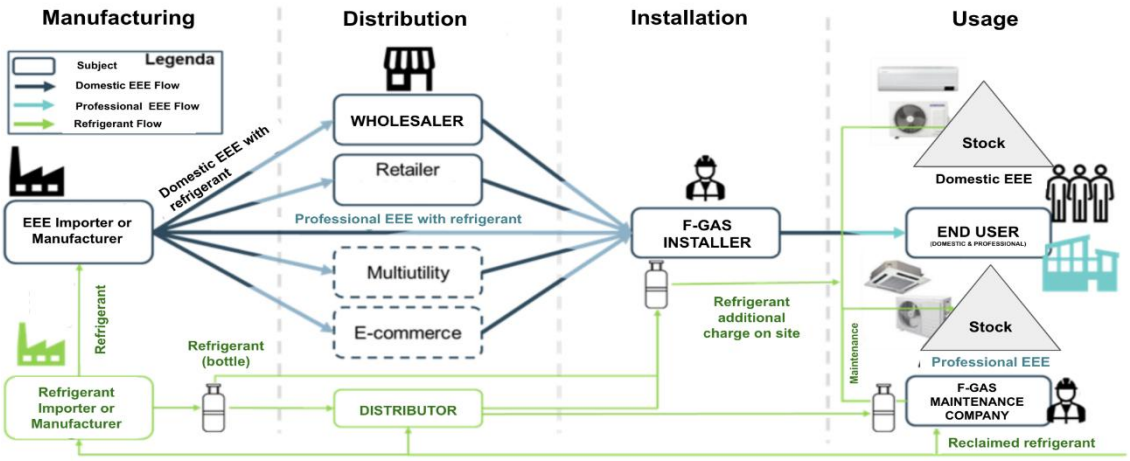


Figure 8: Supply chain flow.

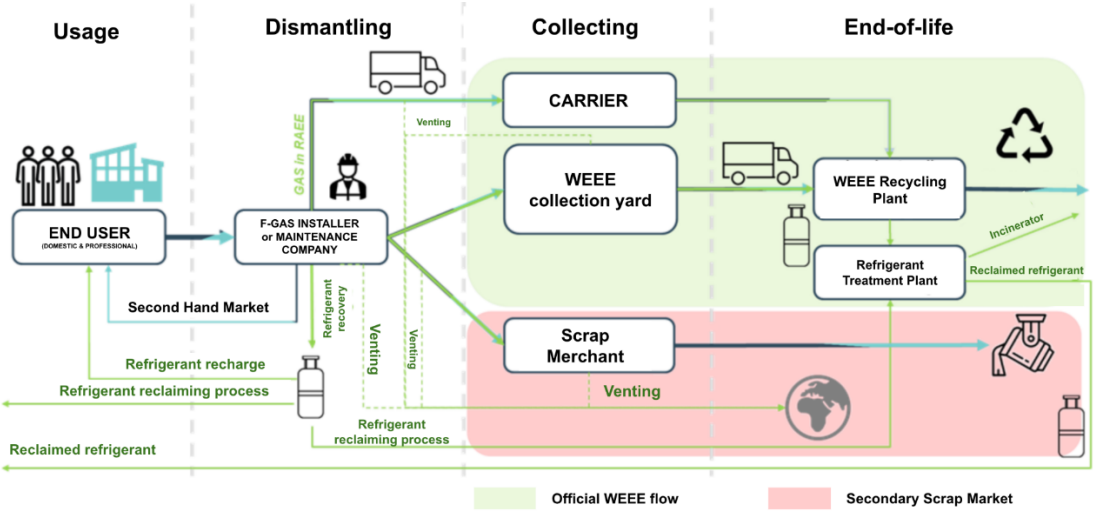


Figure 9: End-of-life flow.

At the end of the usage phase, the customer calls an installer to replace the obsolete or broken appliance with a new one. The customer can avail of the "one-for-one" service, under which the installer is obliged to collect the old WEEE at the time of sale and subsequent installation of the new one. The removal procedure also includes the obligation for the installer to safely recover the refrigerant contained inside the appliance.

Once the product has been removed, for the management and treatment of the WEEE, the installer can turn to various subjects as Collection Centers (CdR), Grouping Locations (LdR) or Treatment Plants, who, however, operate with different levels of competence and traceability.

These collection subjects are typically used for the disposal of Domestic WEEE. Professional units can be more difficult to manage. In case of large size equipment, the installer can request direct collection by an accredited carrier directly on the site where the unit has been removed. Otherwise, if the Professional WEEE is of limited size, the installer himself can take care of its delivery to the Collection Centre. Whatever solution is chosen for the transport of waste, treatment plants represent the correct final destination for the management of WEEE and for the recycling of their components and materials.

In Italy, in parallel with the official WEEE flow, there is still a significant tendency to provide the end-of-life product to the secondary scrap market that consists of the so-called "white vans" network, "scrap yards" and to not certified plants for the WEEE treatment. This unofficial and therefore untracked management circuit becomes of interest to operators when waste

management is seen as a burden in terms of time and costs, mainly due to the bureaucratic procedures that must be followed.

Among the WEEE categories, air conditioners today and heat pumps in the near future are considered valuable in terms of materials and refrigerant contents. Due to their high copper, aluminum and iron content, they are highly requested by those who intend to resell the materials to make an easy profit, without respecting the current regulations.

Erion Professional's “Exceed Clima” programme
WEEE equipment like air conditioners and heat pumps are considered “intrinsically sensitive”, due to the:

a) High economic value of the materials contained in the treated products.
b) Difficulty in finding treatment plants that can manage this waste in a virtuous way, extracting and separating the various components (such as F-gases) with the aim of benefiting the environment.

These are the main reasons why the secondary scrap market is today much more than a risk for the WEEE HVAC collection system.

The Exceed Clima service is the first voluntary collection and recycling program addressing Professional WEEE that complements the traditional management carried out with a "one-against-zero" and "one-against-one" obligation. The program proposes a different approach to the collection of professional waste. Manufacturers that are shareholders of the Erion consortium decided to make a step forward to support their sales networks and the environment, participating in achieving the ambitious European targets.
Through the Exceed service, the Erion Professional Consortium invests financial resources made available by some members to offer simple and widespread methods to increase the quantities of Professional WEEE collected in Italy.
Furthermore, the consortium offers an environmental training service to operators (whether they are installers, wholesalers or other professionals), it manages their registration in the Register of WEEE subjects, and it offers them support to all administrative procedures.

Currently, with the Erion Exceed Clima program, the consortium manages, on behalf of the supporting manufacturers, relationships with professional end users and wholesalers, who can directly request Erion to collect the WEEE product on site. The consortium will take any action aimed at managing, disposing and treating the whole equipment and the refrigerant contained according to the prescriptions.
Since its launch in 2023, more than 800 requests for collection have been completed, resulting in about 1,000 tons of WEEE treated. Of these 393 requests were completed (468 tons) in 2024 alone.

Critical issues
There is still a low awareness among installers of environmental issues and the associated regulations. From some analyses and studies made by the Erion Professional Consortium, it is clear that installers have a limited knowledge of the best way to manage end-of-life equipment. On top of this, they feel that the secondary scrap market is as reliable and compliant with the law as the official WEEE flow.

According to the analyses carried out for the year 2021, 148,000 tons of new equipment (air conditioners and heat pumps) have been placed on the market, of which 120,000 tons belong to the domestic segment and 28,000 tons to the professional segment. In the same year, the stock of installed units consisted of 20.7 million of domestic air conditioners and heat pumps plus 9,6 million of professional equipment.

Assuming a replacement rate of 45% for domestic and 90% for professionals, we can estimate that in 2021, WEEE from air conditioning accounted for 78,800 tons (53,600 tons domestic and 25,200 tons professional). According to Erion data, 6,700 tons (6,200 from domestic and 500 from professional) were collected through the official WEEE flow, while we can assume that the remaining 72,100 tons (47,400 domestic and 24,700 professional) have been delivered to the secondary scarp market.

Data confirms the whole official WEEE flow as a bureaucratic, complex, and expensive system that is not able to provide the expected results and benefits, at least for HVAC products. Despite a scenario that has improved over the years, the rules in place are still difficult to understand and apply. Installers perceive the secondary scrap market as a simpler, quicker and profitable solution because the active participants are willing to pay for getting the units scrapped.

Conclusions: which are the challenges and opportunities for the industry?
To increase the quantity of equipment addressed by the official WEEE flow, it is essential to counteract the secondary scrap market. Erion believes that a mix of the actions listed below could lead to significant improvement:

1. Enhance training and support activities aimed to increase awareness among installers to make the right choice between the official WEEE flow and the secondary scrap market.
2. Facilitate installers' access to the existing layers of equipment collection and test new ones. Similarly to what happens for consumer electronics, apply the "one-to-one" take-back principle to domestic equipment by using the widespread network of wholesalers' points of sale.
3. Put in place an incentive system that rewards installers who deliver equipment to the official WEEE flow. Sharing with them a portion of the value embedded in the scrapped product could be a way to include more installers on the right side of the WEEE collection flow.

Anyway, we do believe that the most effective tool for succeeding is a never-ending dialogue with all the stakeholders involved in this complex process and lawmakers.

4.5. France: Strategies and goals to collect, recover, recycle and reuse heat pumps

Today in France, two options exist to comply with the WEEE Directive. The manufacturer can either individually organize the collection and waste treatment program or subscribe to an “eco-organism” agreed for the collection and treatment of the relevant category of EEE [11].

Currently, all manufacturers subscribe to an “eco-organism”. Having individual collection programs implies a strong commitment, as manufacturers are not directly in touch with the end-users.

The EEE sector can benefit from a “repair” funds defined in the French regulations (article L. 541-10, “Code de l'environnement”, AGEC law and “décret n° 2020-1455 du 27 novembre 2020”). These funds aim to support the repair of a product out of warranty; it reduces the end-user cost. It concerns all categories of EEE, except for photovoltaic panels and lamps. The eco-organisms “Ecologic” and “Ecosystem” have a mutualized repair fund. The repairers can be labeled with the “QualiRépar” label to benefit from these subsidies.

Since 2023, France aims to have a minimum of 2% of used EEE reused or repaired to be reused. Every “eco-organism” has a fund dedicated to reuse, representing a minimum of 5 % of the money they collect. These funds were created in 2022.

Concerning the heat exchange equipment (Category 1) which includes heat pumps, French regulation also sets different goals for collecting (65 % of Cat. 1 EEE), recycling (80 %) and recovering (95 %).

4.6. Ebm-papst take-back system

ebm-papst, a supplier of fans, motors, and electronics for heat pumps, is committed to shifting from a traditional linear business model towards a circular economy. This transformation is driven by several key motivations. The company aims to reduce its environmental footprint and support broader climate goals by extending product lifespans and minimizing waste. Secondly, increasing resource scarcity and the need to lessen dependence on virgin raw materials push the company to adopt resource-efficient solutions. Thirdly, compliance with growing regulatory requirements, such as the Ecodesign Directive, the European Union Green Deal, and anticipated updates to the Ecodesign for Sustainable Products Regulation (ESPR),

forms a major part of ebm-papst's strategy. Lastly, the company recognizes that customers and society increasingly expect transparency and sustainability in product design and after-use management.

To achieve these aims, ebm-papst is adopting circular practices including designing for longer product use, modular construction, repair and refurbishment, and enhanced recyclability of its components. The company is also piloting digital solutions, such as condition monitoring and predictive maintenance, to support lifecycle management and data-driven decision-making. The company anticipates several challenges in these efforts. There is a lack of standardized data infrastructure across the supply chain, which hampers efficient collection and exchange of lifecycle data. Legacy product platforms impose design constraints, making it difficult to fully implement circularity for existing product lines. Customer incentives for returning products are limited, and regulatory fragmentation between countries complicates the operation of international take-back and recycling schemes. Addressing these challenges will require continued innovation, cross-sector collaboration, and regulatory alignment.

One of the key circular initiatives underway at ebm-papst is the development of a take-back system for end-of-use and end-of-life fans, motors, and electronic components used in heat pumps. The ambition is to implement a structured approach to address R-strategies, for collecting, disassembling, and recovering valuable materials and parts from products reaching the end of their useful lives, also including repair and refurbishment. This initiative is currently in the planning and evaluation phase. Central goals include building partnerships with original equipment manufacturers, service partners, and recyclers; establishing reverse logistics and exploring the use of digital identifiers to improve traceability and support efficient disassembly. The take-back system aims to reduce material waste, enable the reuse of critical resources, enable second life of products, and contribute to the overall sustainability of the heat pump sector. By improving product recovery and closing material loops, ebm-papst seeks to strengthen its role in the circular economy as both a supplier and an innovator. A more detailed description of the ambitions in the take-back system can be found in Appendix 2 – ebm papst– take-back strategies for heat pumps and their parts.

4.7. Master thesis conducted by Aksel Nordvig Ladegaard and Antoine Linder from the Technical University of Denmark in collaboration with Viessmann

A recent master thesis (Ladegaard & Linder, 2023) conducted in collaboration with Viessmann (now part of Carrier) and the Technical University of Denmark provides valuable insights into the challenges and opportunities of implementing take-back systems for heating systems, including heat pumps [12]. The research shows that, in current practice, the vast majority of residential heating systems are disposed of as undifferentiated mixed metal scrap, with almost no components intentionally recovered for reuse or high-quality recycling. Installers and service providers usually remove the entire unit at end-of-life, sending it for bulk disposal; occasional removal of circulation pumps or copper parts may occur, driven by material value rather than a systematic circularity strategy. This limited component harvesting reflects a lack of convenience, incentives, and established procedures for selective dismantling at installer level [12].

The thesis combined semi-structured interviews with key stakeholders and targeted desk research to explore take-back systems for heat pumps. In addition, the authors used user activity cycles to map out the different stages and interactions involved in the life cycle of heat pumps. This mapping helped clarify the practical context in which a take-back system would be implemented, highlighting where and how end-of-life products could be collected and processed.

To address the challenges, the thesis analyses three main take-back system configurations: 1) incentivized recovery of select components by installers, 2) bulk collection of used products at installer premises for specialist treatment, and 3) curbside collection directly from end-user homes [12]. All three models focus on recovering a small number of high-value components - typically 1–5 per unit - that can be remanufactured by original equipment manufacturers (OEMs), while the remainder is recycled as scrap. Quantitative analyses in the study show that these approaches can deliver an 8-11% reduction in the carbon footprint compared to the current baseline, although energy savings are minor due to increased logistical requirements

[12]. The research finds that logistics - especially transport and container handling - represent the largest share of costs in all scenarios, with the economic viability of take-back dependent primarily on OEM willingness to pay for recovered components.

A notable finding is that while all three approaches offer modest environmental benefits, the bulk collection configuration demonstrates the highest economic potential due to efficiency gains in centralized processing. However, most costs are fixed, and the business case for take-back systems is only feasible if sufficient component value can be realized through remanufacturing partnerships with OEMs.

Based on the insights, the thesis proposes a practical bulk collection solution designed to maximize both logistical and environmental performance. In this model, installers collect end-of-life heat pumps and other heating systems at their own premises, accumulating them in bulk - typically in dedicated containers [12]. Once a sufficient quantity is reached, the units are transported together to a specialized treatment facility where components of interest are selectively removed for remanufacturing or reuse, and remaining materials are sorted for high-quality recycling. This centralized approach reduces per-unit handling and transport costs, increases traceability, and enables more efficient deployment of skilled labor and specialized equipment for disassembly and material separation. The solution was developed with flexibility in mind, allowing adaptation for different product categories and scales, and incorporates practical considerations such as minimizing participation barriers for installers and fostering collaboration with OEMs from early stages. An overview of the proposed solution is illustrated in Figure 10.

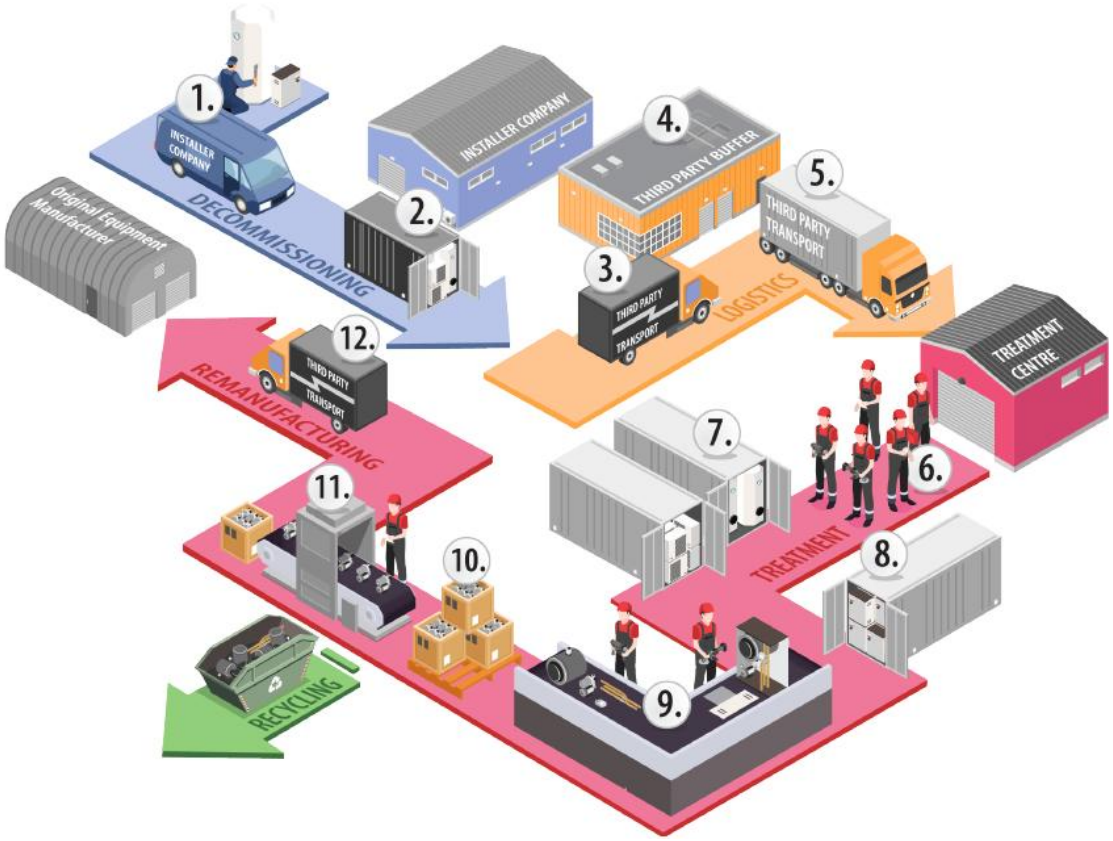


Figure 10: Schematic of proposed solution for Viessmann take-back system [25].

4.8. General learnings from take-back system cases

In summary, the review of take-back strategies for heat pumps and related components reveals that, while the number of established systems is currently limited, practical examples such as the collaboration between Grundfos and NIBE demonstrate that effective take-back solutions are possible. Implementing reverse logistics is complex and requires strong partnerships across the value chain, with particular emphasis on aligning the interests and

actions of all stakeholders, including installers, manufacturers, and suppliers.

Ensuring product data traceability throughout the lifecycle is both important and challenging, as reliable data enables better sorting, recovery, and compliance. Collaboration between heat pump manufacturers and original equipment suppliers is essential to support these processes. Additionally, managing the collection and transport of end-of-life products, especially across national borders, poses regulatory obstacles that must be addressed.

From an economic perspective, the costs associated with collection and processing are significant, making scale an important factor in achieving a workable business case. While economic viability can be demanding, social and environmental benefits also play a key role in justifying take-back systems. Finally, experience shows that beginning with small-scale experiments allows organizations to learn from practice, identify barriers early, and refine their approach before scaling up. These general learnings provide important guidance for companies and stakeholders aiming to advance circular practices in the heat pump sector.

5. Task 2.2 - Research projects that focus on circularity and sustainability in domestic heat pumps

For many years, the heat pump industry has focused primarily on improving energy efficiency and ensuring safety with respect to refrigerants. These aspects have been critical in reducing greenhouse gas emissions during the usage phase of heat pumps. However, as the carbon intensity of the electricity grid continues to decrease, the material footprint of heat pumps is becoming increasingly relevant in efforts to reduce their overall environmental impact.

While material efficiency has not been the primary focus in the past, both market demand and regulatory developments are now driving increased attention towards this aspect. Material efficiency requirements for heat pumps are expected to feature in upcoming regulations, while the market is beginning to recognize the value of incorporating circularity and sustainable materials into product design to improve the lifecycle impact of heat pumps. Given this emerging area of focus, there is a need for research studies to explore the intersection of material efficiency, ongoing circular economy trends, and the transition to alternative refrigerants.

Fortunately, the need for research into heat pumps and circularity is gaining traction. This is evident, for example, in the German National Circular Economy Strategy, which came into force at the end of 2024, and which includes a specific section on heat pumps [13]. The 8th Energy Research Programme from the German Federal Ministry for Economic Affairs and Energy (BMWE) [14] also includes the topic. The programme emphasizes the circular economy as a key strategy to enhance resource efficiency and drive climate neutrality. Research priorities include extending product lifespans, improving recycling processes, developing sustainable materials, and fostering innovative circular business models. Projects are encouraged to address areas such as reducing waste, reusing materials, and minimizing reliance on critical raw materials. Additionally, studies on societal acceptance and the economic impacts of circular practices are highlighted as necessary. International collaboration and knowledge transfer are also recognized as vital to accelerating progress and adopting best practices globally.

When looking at the circular economy in general, Europe is experiencing a significant increase in scientific research. In 2023, nearly 3,894 scientific articles were published on circular economy topics, highlighting a growing knowledge base that supports policymaking and innovation [15]. However, to the knowledge of the project participants, there is currently no comprehensive overview of projects specifically focusing on heat pumps and the circular economy. This section aims to provide insights into identified projects in this area.

The projects included below were asked to answer the following questions in their description of the project:

- What is the purpose of the project?
- How does this project contribute to the circularity of heat pumps?
- What role do regulatory frameworks play in shaping research priorities?
- How market-ready are the circular practices assessed?

5.1. Viessmann's efforts to decarbonise heating throughout the value chains and the CE-RISE project

This section highlights Viessmann's practical work to increase circularity in domestic heat pumps and presents the CE-RISE project. CE-RISE is a European initiative focused on improving material transparency and circularity through digital solutions such as the Digital Product Passport (DPP). Viessmann's case study shows how this approach is applied in the heat pump sector and outlines key benefits and challenges.

The CE-RISE project

CE-RISE (Circular Economy Resource Information System) is a four-year EU project under Horizon Europe, running from 2023 to 2026 with a total budget of €9.1 million. Coordinated by NILU and including 26 other partners, the project's main goal is to develop digital tools, in

particular an information system for Digital Product Passport (DPP), that provide full transparency on materials, components, and products across the entire value chain for electrical and electronic products. The focus is on critical raw materials (CRMs), circular processes, and minimizing the environmental footprint.

The DPP will ensure that data on material content also including recycled materials, product lifespan, and the potential for repair, reuse, refurbishment, and recycling is connected to a product throughout its life cycle. The intended benefits include:

- Promoting efficient repair, refurbishment, and recycling.
- Simplifying compliance documentation for both authorities and customers.
- Facilitating optimal recovery and reuse of critical and valuable resources.

Key figures	
Timeline	2023-01-01 – 2026-12-31
Funding and funding scheme	European Health and Digital Executive Agency (HaDEA) Cluster 4: Digital, Industry and Space
Number of partners	26
Project webpage	https://ce-rise.eu/
Keywords	Circular economy, reuse, repair, remanufacturing, recycling, raw materials, resource efficiency
TRL level	6-8 (piloting, demonstration, and testing in relevant environments)
Product life stages	Raw material, manufacturing, transportation, use phase, end-of-life (EoL)

Viessmann's case in CE-RISE

Viessmann contributes to the CE-RISE project with a detailed case study centered on its Vitocal 250-A heat pump, where the Digital Product Passport (DPP) solution is being put into practice. The DPP compiles comprehensive information for each component - including the mass shares of steel, copper, and plastics, manufacturing origin, disassembly options, and possible pathways for reuse or recycling.

Over a typical product lifetime of around 17 years, the total CO_2 emissions for the Vitocal 250-A heat pump are approximately 17.8 tons (17,800 kg CO_2-equivalent). Of this, about 15.3 tons come from the use phase (mainly electricity consumption), while the remainder (about 2.1 tons) arises from raw material extraction and production. Steel is the largest material contributor, with each unit containing 103 kg steel, plus smaller quantities of copper, plastics, and electronics.

Crucially, the project analysis shows that enabling the 5R principal across the value chain can reduce the product's embodied carbon footprint by as much as 54%. These savings are enabled through the DPP and can actively guide more sustainable material decisions throughout the value chain. Even more substantial carbon savings can be achieved by combining the heat pump with renewable energy solutions such as solar PV and batteries; for instance, integrating solar PV and a battery storage system could potentially bring down the use-phase CO_2 footprint by about 50% by the first year.

Furthermore, optimizing logistics - for example by locally sourcing components and avoiding long-distance shipping - can save 131 kg CO_2 per unit. Overall, the Digital Product Passport provides the robust data backbone for tracing materials, managing end-of-life flows, and maximizing environmental and business value throughout the product lifecycle.

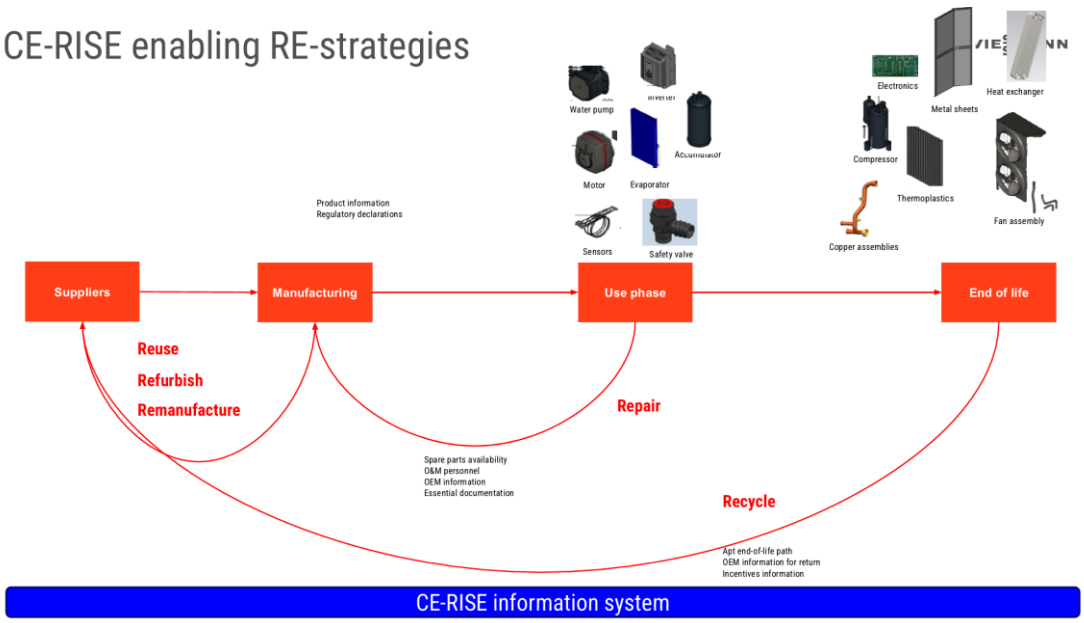


Figure 11: CE-RISE RE-strategies for Viessmann heat pump.

Following specific insights and challenges are pointed out by Viessmann:

- Data quality and supplier collaboration: Viessmann notes that accessing complete and reliable data from suppliers is a real challenge, especially for complex items such as printed circuit boards and thermoplastics. Many suppliers are not yet able to deliver the required information, which limits traceability and the potential for recycling.
- Business implications: Experiences so far show that digitalization and transparency via the DPP support compliance with new and forthcoming EU regulations (such as the Ecodesign for Sustainable Products Regulation, ESPR) and create opportunities for material recycling and the development of circular business models.
- Circularity impacts: The DPP data is made accessible to manufacturers and waste handlers, enabling more components to be recovered from end-of-life heat pumps for repair or recycling, and providing documentation on environmental gains throughout the value chain.

Summary

Viessmann's work within CE-RISE demonstrates how digitally traceable and documented circular processes can be implemented in practice. Lessons learned indicate that the project's tools enable both internal and external sustainability goals, provide measurable reductions in the carbon footprint via materials like steel, and support collaboration that can make the entire heat pump value chain more circular and resilient. The following key points are stated:

- The DPP system is built around information such as bill of materials, CRM content, product lifetime, and repair, refurbish, or recycling potential.
- It is designed to support compliance with EU regulation including ESPR, the "Right to Repair," and upcoming directives under the Green Deal and Sustainable Products Initiative.
- The overall goal is to equip stakeholders across the value chain with evidence-based insights for environmentally and economically sound decision-making, enabled by data transparency on material use and recirculation strategies.

5.2. Comparing R-Strategies for residential heat pumps by RWTH Aachen

The description in this section is summarized from: Vering, C., Knieps, C., Beckschulte, M., and Müller, D., Towards sustainable heat pump (re-)cycles: Integration of circular strategies into the life cycle assessment of heat pumps, submitted to the CISBAT conference 2025.

This study incorporates circular strategies into an existing life cycle assessment (LCA) tool designed for heat pumps and refrigerants in existing buildings [16]. The assessment covers the production of heat pumps and refrigerants, as well as the operation of heat pumps. Circular strategies (R-Strategies) include several end-of-life approaches, such as reduce,

remanufacture, repair, and recycling. These strategies are modeled as scenarios and implemented in the tool allowing the evaluation using the ReCiPe method.
Building on expert interviews, literature research, and the ecoinvent database, an ecological and economic evaluation was conducted to explore the potential of circular strategies.

Assuming a grid mix of 2020 (2040) in Germany following ecoinvent dataset, perfect remanufacturing reduces the impact on human health by 10% (23%). For ecosystem quality the reduction is about 2% (7%). With respect to material resources, it is 3% (5%). The results indicate that the impact on circular strategies increases with decreasing grid mix, and, hence, increasing impact of the production and end-of-life phase. Thus, circular strategies are already more important in countries with lower operational phase impact, and circular strategies will be even more important when grid mixes reduce in the future as a part of the energy transition.

The findings are shown in Figure 12 and reveal several key insights:
1. The tool effectively calculates the impacts of R-Strategies for heat pumps and refrigerants.
2. Compared to a linear economy model, circular strategies reduce the raw materials and energy required for production. This shift minimizes environmental impacts production and disposal while also lowering the risks associated with import dependency.
3. Regular maintenance contracts every two years may, paradoxically, increase environmental impacts and prove more expensive compared to maintenance intervals of ten years.
4. Data availability is limited, and existing databases lack harmonization, presenting challenges for further research.

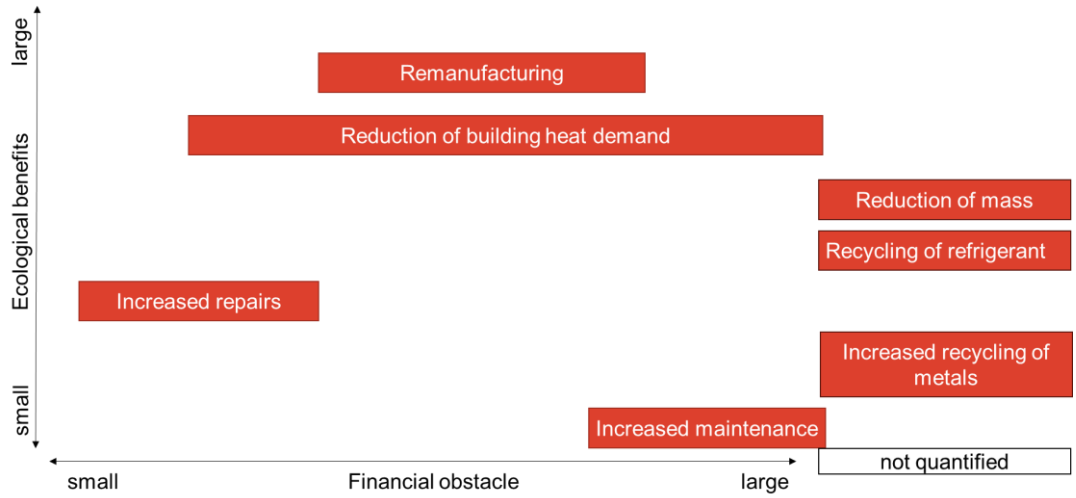


Figure 12: Integrating R-Strategies into the LCA of heat pumps.

Overall, the results underscore both the potential and the challenges of advancing circular economy practices for heat pumps, aiming to safeguard ecosystems, human health, and natural resources.

5.3. Towards Circular Design and Business Models for Sustainability of the next generation heat pumps. (Daikin PhD project)

Introduction

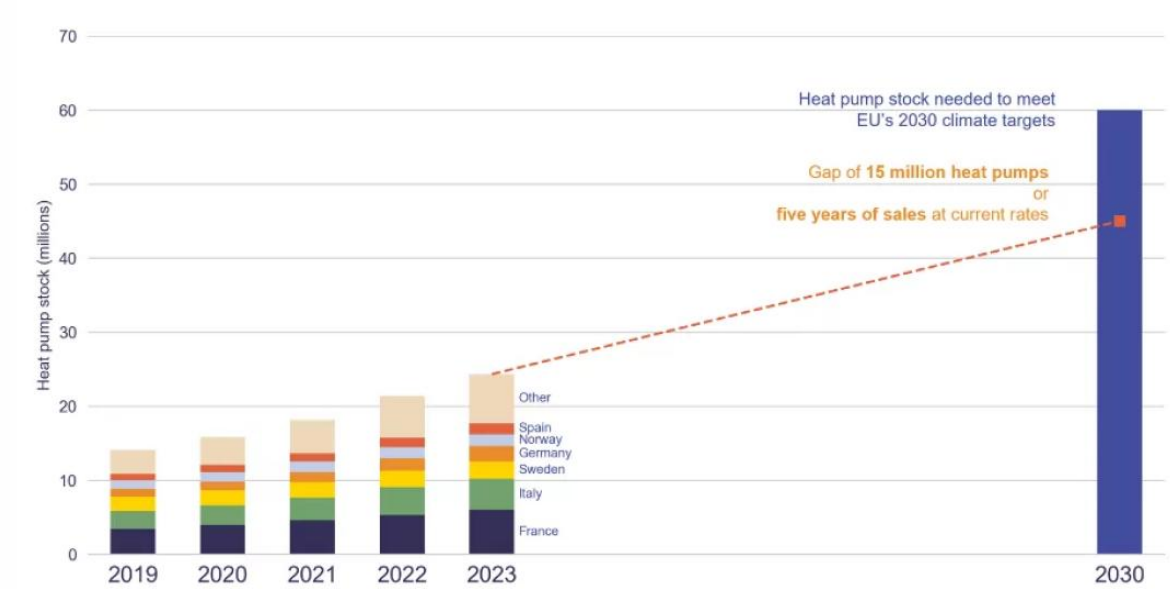


Figure 13: Current stock, production of heat pumps and goals of the EU.

As shown in the chart above, approximately 23.96 million heat pumps had been installed in Europe by the end of 2023. If annual sales remain around the 2023 level of 3 million units, Europe will only reach 45 million installations by 2030. This figure falls 15 million units short of the stock needed to meet the EU's 2030 climate targets, which translates to a 25% gap[1] [2]. Bridging this gap would require maintaining, or ideally increasing, current sales over at least five additional years.

This shortfall highlights a critical need: improving not only the adoption of heat pumps but also their circularity and sustainability. As the heat pump sector scales up to meet climate objectives, addressing the knowledge gap in circular design and business models becomes urgent. Without this, expanding production may lead to increased material consumption, resource depletion, and waste - contradicting the EU's broader goals for a circular economy. In response to these challenges, a collaborative research initiative between Ghent University and Daikin has been launched. This project aims to develop decision support guidance for the circular design and business models of next-generation heat pumps. The project seeks to bridge current knowledge gaps and contribute to the creation of more sustainable, resource-efficient heating solutions aligned with the EU's environmental goals.

Challenges in circular design and business models

Designing heat pumps for circularity involves addressing several interrelated challenges:

- Identifying the optimal Circular Economy (CE) strategy: This involves determining whether to preserve product function, product integrity, components, materials, or embodied energy. These strategies relate closely to the well-known R-strategies such as reuse, remanufacture, recycle, refurbish, and reduce.
- Selecting appropriate sustainability indicators: Indicators must capture not only environmental but also social and economic impacts. These may include material recovery rates, recycled content, carbon footprint, social equity metrics, and economic viability. Additionally, indicators assessing the criticality and circularity of materials (e.g., those on the EU's Critical Raw Materials list) must be incorporated.
- Value chain integration: Circular economy solutions often require cooperation across the

[1] Pascal Westring et al. European Heat Pump Market and Statistics Report. The European Heat Pump Association (EHPA). 2024.

entire lifecycle - from manufacturers and users to waste processors and recyclers. Isolated interventions are insufficient; systemic change involving multiple stakeholders is needed.

These challenges highlight the need for a comprehensive approach that integrates design, assessment, and strategic planning across the product life cycle.

Project goals and methodology
The overarching goal of this research project is to develop decision support tools that facilitate circular design and business strategies for the next generation of heat pumps. The methodology follows a sequence of work packages, and some of them are:

State-of-the-art analysis
The first step is to review the status of sustainability in the HVAC sector. This includes identifying existing eco-design approaches, end-of-life treatments, and potential for improvement through novel circular economy strategies.

Material flow analysis and impact quantification
A detailed Material Flow Analysis (MFA) will be conducted for heat pumps and their components across their life cycle stages: upstream supply, manufacturing (including at Daikin), use, and end-of-life. The MFA will cover multiple countries and integrate time dynamics to reflect future scenarios.
From the MFA, the project will quantify sustainability impacts using life-cycle thinking. This includes calculating environmental footprints (e.g. CO_2 emissions), social implications (e.g. labour conditions in supply chains), and economic performance. The results will inform circularity and sustainability strategies.

Scenario development and assessment.
Collaborating with Daikin experts, the project will formulate innovative scenarios for circular business strategies at product, component, and material levels. These scenarios will incorporate different R-strategies and will be assessed for their material and functional feasibility, economic viability, and environmental and social performance.
Prospective assessments will quantify the potential impact of each scenario, allowing for comparison and prioritization. This work will culminate in the creation of decision support guidance, aimed at helping companies like Daikin implement circular strategies effectively.
This research project, running from 2024 to 2028, is funded by Daikin and involves collaboration between two participants – Daikin Europe and Ghent University. It focuses on advancing the circularity and eco-design of heat pumps, aiming to support sustainable product development and circular business models within the heating sector.

Key figures of the project	
Timeline	2024-2028
Funding source	Funded by company: Daikin Europe
Number of participants	2
Keywords	Heat pump, circularity, eco-design

Conclusion

As Europe accelerates its transition to low-carbon heating technologies, the pressure on the heat pump industry to deliver both scale and sustainability intensifies. Meeting the EU's 2030 climate targets will require not only increasing sales but also ensuring that heat pumps are designed and managed within a circular economy framework.
This collaborative research project between Ghent University and Daikin directly addresses key knowledge gaps in circular design and business models for heat pumps. By integrating end-of-life strategies, material flow analysis, and prospective sustainability assessments, the project will deliver decision support guidance that can serve both industry practitioners and academic stakeholders. Ultimately, this initiative aims to contribute to the development of next-generation heat pumps that are not only energy-efficient but also circular, resource-responsible, and aligned with long-term climate and sustainability objectives.

5.4. Smart-Pumps project

The Smart-Pumps project is a Horizon Europe-funded research initiative that aims to revolutionize the design, manufacturing, and lifecycle management of domestic heat pumps. Coordinated by the Hellenic Mediterranean University (Greece) with collaboration from multiple European partners, the project focuses on introducing advanced design, digital manufacturing, and circularity principles to improve both the environmental footprint and operational performance of residential heat pumps.

Key figures	
Timeline	2024–2027 (Ongoing)
Funding and funding scheme	Horizon Europe
Number of partners	6 and coordinated by Hellenic Mediterranean University, Greece
Project webpage	https://smartpumps-project.eu/
Keywords	Heat pumps, circular economy, hybrid manufacturing, recycled materials, sensors, digitalisation, life cycle analysis, sustainability
TRL level	TRL 3 at the project beginning TRL 5 at the end of the project
Product life stages	Raw material, manufacturing, use phase, end-of-life (EoL)

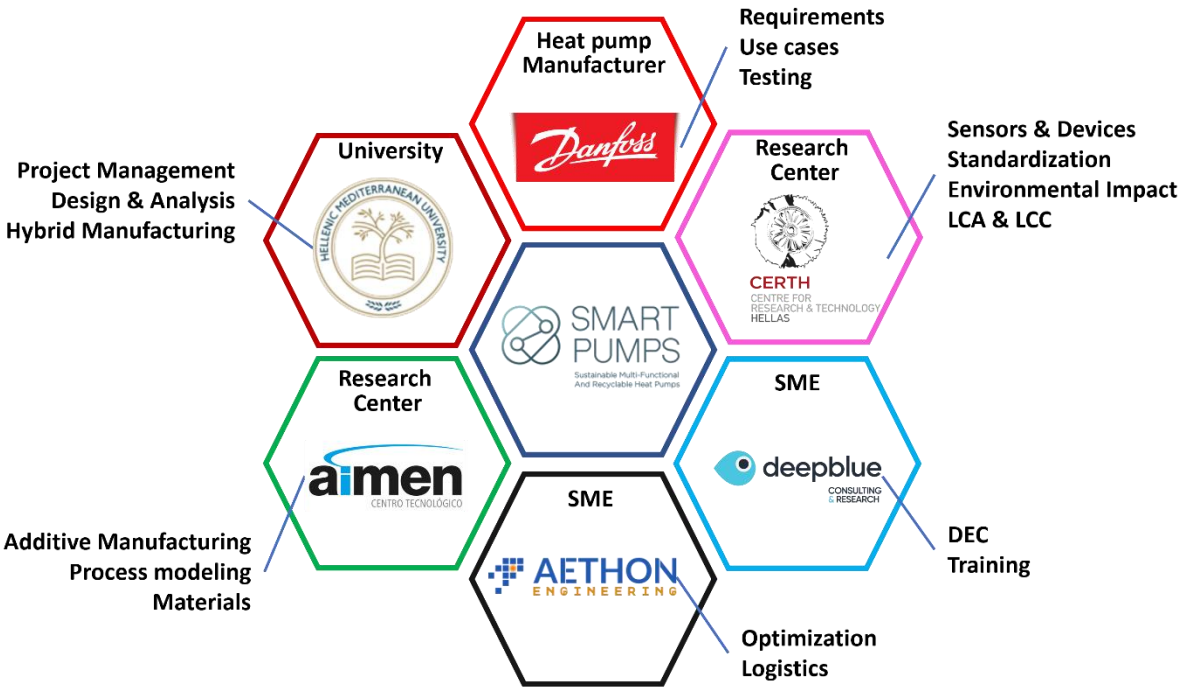


Figure 14: Project consortia for the Smart-Pumps project.

Smart-Pumps seeks to develop next-generation heat pumps that are not only energy efficient but also manufactured with recyclability and sustainability in mind. The main purposes are:

- To redesign heat pump components and overall architecture for higher efficiency and modularity.

- To integrate recycled materials and ensure that new designs facilitate high rates of component and material recyclability.
- To embed sensors and smart technologies for advanced performance monitoring and optimization.
- To establish innovative hybrid (additive and subtractive) manufacturing processes that enable both material flexibility and the incorporation of smart functions.
- To develop training modules for workforce skills in digital manufacturing and maintenance of smart heat pumps.

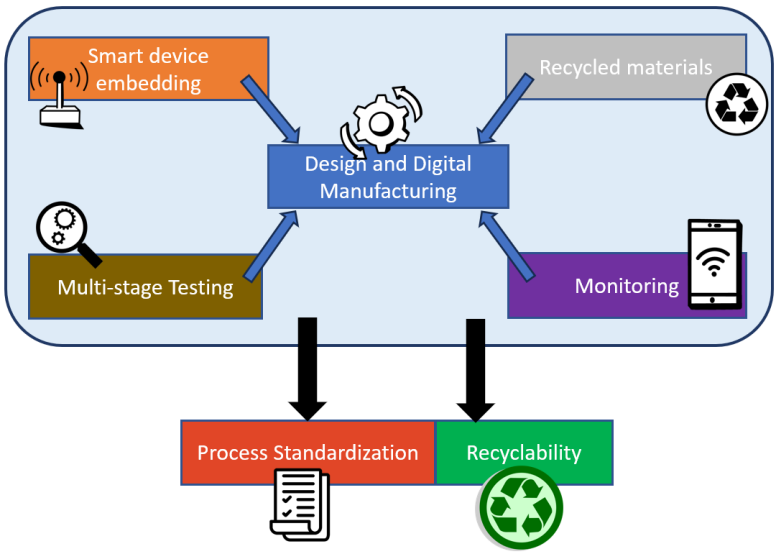


Figure 15: Smart-Pumps novel approach in Design & Digital Manufacturing of Heat Pump components.

Contribution to circularity of heat pumps
There are a number of circularity principles included in the Smart-Pumps project:

- **Material circularity:** The selection and testing of recycled materials guide the design of key components such as heat exchangers, with a focus on ensuring both performance and end-of-life recyclability.
- **Design for disassembly and reuse:** Hybrid manufacturing allows for the production of components that can be more easily disassembled or refurbished.
- **Embedded digitalization:** The use of embedded sensors supports remote condition monitoring, facilitates predictive maintenance, and enables improved lifecycle management and reuse.
- **Life cycle analysis (LCA):** Both baseline and improved heat pump components undergo LCA and life cycle cost assessment (LCC) to quantify environmental and financial benefits of the new approach compared to conventional designs.

The project recognizes the importance of evolving EU policies supporting circular economy and eco-design. Compliance with current and upcoming requirements facilitates alignment with European climate and material efficiency targets. The Smart-Pumps team leverages knowledge of regulation, such as ecodesign directives and circularity metrics, to ensure applicability and relevance of their solutions for future regulations and market demands.

Expected outcomes
Smart-Pumps is currently in its development phase, with component specifications and prototypes being defined and tested. Key expected outcomes include:

- Development of two prototype heat pumps utilizing smart functionalities and manufactured from recycled or recyclable materials.
- Manufacturing protocols and best practice guides for circular, digital production of heat pumps.
- Models for small-scale, on-site manufacturing and assembly to reduce transport

needs and material flow impacts.
- Training curricula for multiple stakeholder groups including installers and engineers to support uptake of new manufacturing and maintenance practices.

The project expects that its new generation of heat pumps will combine improved operational efficiency and resilience with a lower environmental footprint, thus supporting increased adoption of circular practices in the European heat pump industry.

6. Task 2.3 – Status on circular economy transition and latest updates from authorities on circular economy and material efficiency impacting heat pump product design

This section focuses on the latest announcements and updates from relevant authorities in relation to circular economy and material efficiency aspects. The aim is both to provide a state-of-the-art description on a European and national level and to give perspectives on what the future brings. By exploring the current frameworks and initiatives across various countries, this section will reflect the differences between the participating countries in the project. Additionally, the discussion will incorporate forward-looking insights that reflect anticipated trends, technological advancements, and regulatory changes shaping the future of circular economy practices.

While some general information is included, the focus will, as much as possible, remain on heat pumps and heating products to ensure relevance for the project.

6.1. European state-of-the-art on circular economy

The European Union is making some progress in its transition towards a circular economy, with efforts aimed at reducing resource use, minimizing waste, and promoting sustainable business and consumption practices. While progress has been made, challenges remain in scaling up circular practices to achieve a broader impact. Each European uses about 14 tonnes of material and generates 5 tonnes of waste annually [17]. This is among the highest levels globally and beyond sustainable limits, posing barriers to narrowing material cycles in Europe [17]. On the positive side, the EU has managed to grow its economy while using a stable amount of resources and generating a stable amount of waste, achieving a modest level of decoupling.

The European Union (EU) has established a strong policy framework to support circularity, starting with the adoption of the first Circular Economy Action Plan (CEAP) in 2015. Since then and until early 2025, 24 out of 27 EU Member States have implemented national circular economy policies, including strategies, action plans, and other frameworks. The most recent evaluation of the circularity rate from 2023 shows that, with a circularity rate of 11.8%, Europe consumes a higher proportion of recycled materials than other world regions, although improvements have been limited in recent years [17].

In 2022, Europe generated €2.1 of economic output per kilogram of materials consumed, which is more than 2.5 times the global average [17]. Despite this progress, material use remains largely linear, with virgin resources dominating material flows, and the circular material use rate (CMUR) stagnating at approximately 11.5% since 2016 [17]. Estimates suggest that the EU needs €55 billion annually to finance its circular economy transformation, and currently there are a total of 4.3 million people employed in the circular economy sector [17].

Although progress has been made in Europe's transition towards a circular economy, significant challenges remain. Improvements can be seen in areas such as waste recycling, resource productivity, and the adoption of circular policies across Member States. However, issues like inefficient material flows, reliance on virgin resources, and limited functionality of secondary markets persist. Monitoring frameworks, while valuable, still fail to address critical aspects like product lifespans and broader circular practices. While Europe has laid a solid foundation for circularity, much work is still needed to achieve systemic transformation.

6.2. National status on circular economy

This section will provide key metrics and information on the state-of-the-art circular economy practices in the participating countries of the project.

6.2.1. Denmark

Denmark's current Circularity Metric stands at 4% [18], which is considerably below the global average of 7.2% as recorded in 2023 [19]. This indicates that the vast majority of materials consumed in Denmark originates from virgin sources rather than being cycled back into the

economy. On a per capita basis, Denmark consumes 24.5 tonnes of materials annually. This is significantly higher than the EU average of 17.8 tonnes per person and the global average of 11.9 tonnes per person. Critically, this consumption level far exceeds the estimated sustainable level of 8 tonnes per capita [18]. A notable 72% of the total extraction required to meet Danish demand occurs beyond its borders. This highlights Denmark's reliance on imported materials and the environmental burden shifted to other regions [18]. The report further explains that the Circularity Metric for Denmark only credits recycling efforts that occur domestically, including materials imported for recycling. Waste sent abroad for recycling is not accounted for in the metric. If these exported recycling efforts were included, Denmark's Circularity Metric would increase to approximately 6%. However, due to Denmark's relatively small economy and limited domestic recycling facilities, proximity to larger economies like Germany often makes it logistically and economically viable to export waste for recycling [18].

Unfortunately, the Circularity Gap Report does not provide specific data or insight into the circularity of heat pumps. Nevertheless, it offers a comprehensive view of the state-of-the-art in Denmark, illustrating the broader context of how the country addresses circularity challenges and opportunities.

6.2.2. Germany

In 2020, Germany extracted and imported approximately 1,287 million tons of raw materials, supplemented by 613 million tons of imported semi-finished and finished goods, leading to a material retention of 611 million tons within the domestic economy. Despite these figures, the circular use of materials remains relatively low, with only about 13% of total direct material use consisting of secondary raw materials. Furthermore, the global demand for raw materials is projected to rise significantly, which necessitates a shift towards resource-efficient practices.

The National Circular Economy Strategy (Nationale Kreislaufwirtschaftsstrategie, NKWS) [13] aims to promote Germany's transformation into a resource-efficient, circular economy. It was developed to reduce primary resource consumption, close material loops, and enhance resource security. Given the pressing environmental crises, such as climate change and biodiversity loss, circular economy practices are seen as essential for reducing greenhouse gas emissions and ensuring sustainable resource management. The NKWS encompasses several key strategies, including waste prevention, material reuse, and resource recovery. It emphasizes sustainable product design, recycling, and the increased use of secondary raw materials in production. The strategy sets ambitious targets for reducing waste and increasing the use of recycled materials, supported by regulatory frameworks and economic incentives. Key measures outlined in the NKWS include the development of binding recycling quotas, the promotion of circular business models, and the establishment of digital tools for tracking materials. The strategy also highlights the importance of international cooperation to foster a global transition to circular economies. Overall, the NKWS aims to contribute to a sustainable, resilient economy in Germany by leveraging innovation, fostering new technologies, and creating a framework that supports the circular economy principles across all sectors.

The NKWS emphasizes the importance of heat pumps in achieving climate protection goals, particularly through their role in decarbonizing heating systems. The strategy outlines the need for a significant increase in renewable energy sources, with heat pumps expected to replace oil and gas heating systems as they must operate with at least 65% renewable energy by mid-2028. While this transition will initially increase the demand for materials like copper, steel, and aluminum for heat pumps, it also aims to reduce the resource requirements for fossil heating systems. The NKWS calls for promoting circular design principles for heat pumps to enhance their upgradeability and repairability, ensuring that consumers can maximize their use. Support for innovative business models, such as "Heating as a Service," is also highlighted to encourage efficient utilization and high-quality recycling of heat pumps. Additionally, the strategy recognizes the need for improved disposal practices, including the development of clear disposal guidelines for companies and users to ensure proper handling of heat pumps, particularly those containing climate-damaging fluorinated gases. Overall, the NKWS aims to foster a more circular economy for heat pumps, contributing to sustainability and resource conservation.

6.3. Future perspectives from EU on circular economy

The number of new developments regarding the circular economy has been limited since the publication of the Task 1 report. However, the European Union is showing its continued commitment to the circular economy by advancing comprehensive new policies and legislation. The upcoming Circular Economy Act, scheduled for adoption in 2026, aims to support the free movement and use of secondary raw materials within the single market, harmonise “end of waste” criteria, and expand producer responsibility [20]. The Act will also create incentives for public procurement that favours products containing recycled materials.

Complementary action is underway through the Critical Raw Materials Act, which supports strategic projects, joint purchasing, and investment in recycling capacity [21]. The EU also plans to address waste management challenges, for instance by incentivising recycling within the region and reviewing VAT rules for second-hand goods [21]. To further scale circular practices, the Commission is launching Trans-Regional Circularity Hubs for collaboration and economies of scale among Member States [21]. Upcoming actions from the EU are listed in Table 1.

Flagship actions – Powering the circular economy: a secure access to materials and resources	**Timeline**
First list of Strategic Projects under the Critical Raw Materials Act	Q1 2025
Ecodesign Work Plan adoption	Q2 2025
EU Critical Raw Materials Centre for joint purchases and management of strategic stockpiles	Q4 2026
Circular Economy Act	Q4 2026
Green VAT initiative	Q4 2026
Trans-Regional Circularity Hubs	Q4 2026

Table 1: List of initiatives related to circular economy in the Clean Industrial Deal [21].

6.3.1. Ecodesign for Sustainable Product Regulation (ESPR)

As part of the ESPR regulation, a preparatory study on iron and steel products is underway that could become relevant for heat pumps. This study aims to provide scientific and economic background to support future EU product policy for steel, helping to identify requirements that can increase the sustainability of steel products placed on the EU market.

6.3.2. Information requirement on GWP information in ecodesign

The domestic heat pumps air-to-air, air-to-water, and ground source still belong to the transitional group of products that remain regulated under the previous framework for Ecodesign and Energy Labelling instead of ESPR. At the time of writing this report (early summer 2025), no new proposals for revisions to the Ecodesign or Energy Labelling Regulations covering these product categories have been published since the latest version in 2023. However, a recent Eurovent position paper indicates that the European Commission is considering the introduction of a global warming potential (GWP) information requirement in future product regulations [22]. While there is no formal proposal yet, the ongoing dialogue between industry associations and the Commission reflects active evaluation of whether GWP reporting would be appropriate and feasible for space heaters and potentially other HVAC products.

7. Task 2.4 - Current business model for circular economy practices related to heat pumps in participating countries

The transition to a circular economy in the heat pump sector is not only about technology but also about transforming the way value is created, delivered, and captured. Circular business models (CBMs) aim to decouple value creation from resource consumption, extend product lifetimes, and reduce waste. For heat pumps, relevant circular strategies include refurbishment, repair and maintenance, reuse, remanufacturing, leasing, and product-as-a-service offerings.

The CIRCit workbook offers a practical three stage model to evaluate the possibility for

circular business models: Sense, Seize, and Transform, see Figure 16. Each stage is broken down into practical steps and supported by tested tools. By following these steps, organizations can move from understanding their current business models to designing and implementing circular solutions.

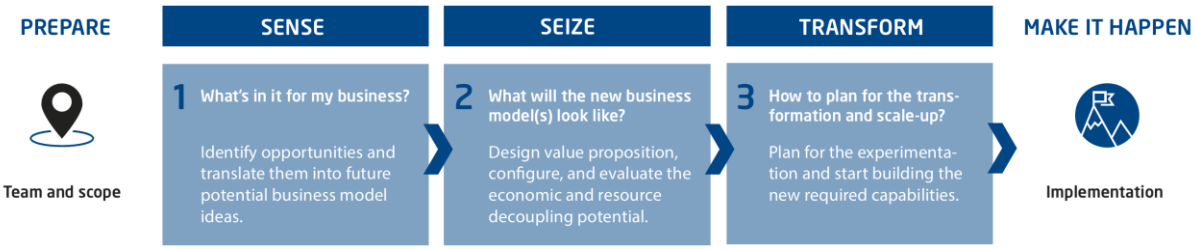


Figure 16: Illustration of three-stage process [23].

Stage 1: Sense – understand and map your current situation
This first stage helps organizations answer, "What's in it for my business?". It begins with mapping where the company is today using the Circular Strategies Scanner, which visualizes how current business models contribute to circular economy strategies, such as repair, refurbishment, or reuse. A SWOT Matrix is then used to analyze internal strengths and weaknesses, as well as external opportunities and threats for circular business models. Next, companies identify key drivers and barriers - such as regulatory changes, customer needs, or supply chain factors - and define where they want to go by conceptualizing business model ideas. The outcome is a shared vision and a prioritized list of opportunities for circularity in heat pumps.

Stage 2: Seize – develop and refine circular business model concepts
The second stage answers "What will the new business model(s) look like?". Here, organizations use tools like the Circular Economy Business Model Configurator to translate ideas into concrete business model concepts. This involves detailing value propositions, mapping customer and end-user journeys, and configuring how value will be created, delivered, and captured. Economic calculators and resource decoupling tools help evaluate the potential benefits and feasibility of each concept, such as estimating cost savings from product life extension or resource recovery. Experimentation roadmaps and pilot projects can then be planned to test and validate assumptions before large-scale implementation.

Stage 3: Transform – implement, scale, and continuously improve
The final stage focuses on "How to plan for the transformation and scale-up?". It involves developing a clear implementation roadmap with milestones, deliverables, and responsibilities. Change management plans address how to engage internal and external stakeholders and build new capabilities. Key performance indicators (KPIs) are established to monitor progress and enable continuous improvement. Regular review cycles ensure that the business model remains aligned with both company goals and external developments.

How to get started
To make the process actionable, organizations are encouraged to start small - perhaps with a single product line or service - and use the provided tools to facilitate workshops or team meetings. Involving a cross-functional team from procurement, R&D, sales, operations, and service can help bring diverse perspectives and ensure buy-in across the organization.

By following the Sense–Seize–Transform framework and using practical tools such as the Circular Strategies Scanner, SWOT analysis, and Business Model Configurator, organizations can move systematically from understanding their current situation to implementing and scaling up circular business models. This approach not only makes the transition more manageable but also helps unlock new value and strengthen long-term competitiveness in the heat pump industry.

7.1. Master thesis conducted by Universiteit Utrecht on Eneco heat pumps

The master thesis "A consumer and supply chain analysis on the circularity of heat pumps" by

Ralph Schrijer explores how the transition from a linear to a circular economy can be applied to the heat pump sector, focusing on the Dutch company Eneco as a case study. The underlying principle is to move away from the traditional "take-make-use-dispose" model and instead keep resources in use for as long as possible through reuse, refurbishment, and recycling.

Framework and methods
The study is structured around four pillars of a circular business model: consumer desirability, technological feasibility, economic viability, and environmental impact. Achieving a balance between these four elements is considered essential for success, see Figure 17.

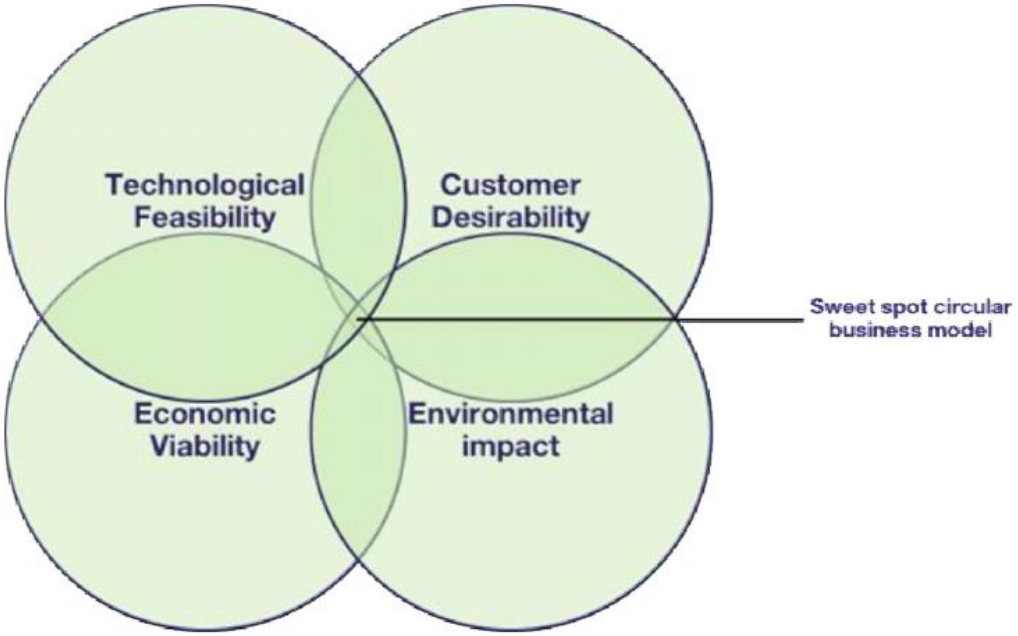


Figure 17: The analytic framework; four pillars of circular business model.

To address these pillars, the research uses a mixed-methods approach. Consumer desirability was assessed through a Discrete Choice Experiment (DCE) involving potential future owners of heat pumps, which provided insight into which circular strategies are most appealing to customers. Technological feasibility, economic viability, and environmental impact were explored through interviews with key actors in Eneco's supply chain, including heat pump producers and the recycling company Refurn. These interviews examined the practicalities of implementing take-back systems, the economic prospects of circular models, and the environmental benefits. Additionally, environmental impacts were evaluated using simplified Life Cycle Assessments (LCAs) to estimate potential reductions in CO_2 emissions and material use.

Key findings
Younger, well-educated, and informed consumers tend to prefer refurbished heat pumps, but warranty and efficiency are more important than circularity alone. Therefore, circular products must match or compensate for these features to be attractive. Producers are generally not equipped to operate take-back or refurbishment processes on their own, making collaboration with specialized partners like Refurn essential for realising circular solutions. The research also finds that circular business models can be profitable, as consumers are willing to pay more for circular features, and new revenue streams may be created. Environmentally, adopting circular business models could lead to significant reductions in CO_2 emissions and material use per heat pump.

Implications
The research suggests that both policy incentives and coordinated internal action are needed to make circular business models successful. The approach used in this study provides a useful benchmark for other companies in the sector considering a transition to circular practices.

7.2. Alfa Laval Brazed-Fusion Bonded Circularity Initiative

Alfa Laval Brazed-Fusion Bonded Circularity Initiative, in collaboration with specialized partners, is focused on recovering and recycling valuable materials from end-of-life heat exchangers.

Recognizing the growing importance of resource efficiency, the project aims to address both environmental and performance challenges within the industrial sector by promoting a circular approach to heat exchanger replacement.

Under this model, customers who install a new Alfa Laval brazed heat exchanger return their old units to Stena Recycling. The used heat exchangers are then dismantled, and up to 100% of the contained metals - primarily stainless steel and copper - are recovered for reuse. This reduces the demand for virgin materials and minimizes the environmental footprint associated with new product manufacturing. For customers, the initiative offers dual benefits. First, they gain access to the latest, more energy-efficient heat exchangers, which help to reduce operational costs and CO_2 emissions. Second, they contribute directly to a more sustainable and responsible product lifecycle, as obsolete equipment is repurposed rather than treated as waste.

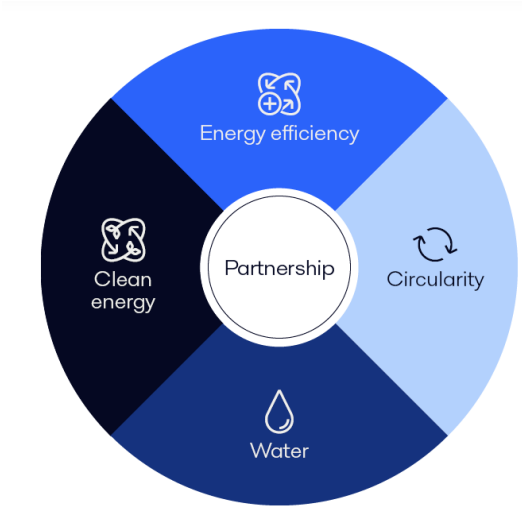


Figure 18: Alfa Laval partnership for accelerating energy efficiency, clean energy, and the circular economy. Source: Alfa Laval.

There are some challenges that the project aims to address as it develops. These include advancing recycling technologies for complex materials, managing variations in metal quality, and streamlining processes for material separation. The project is also working to encourage strong market acceptance, establish clear incentive structures, and build an effective reverse logistics network. Addressing evolving regulatory requirements, including those linked to global supply chains and EU policies, is also a key focus. Through ongoing innovation and collaboration, the project seeks to turn these challenges into opportunities for improvement and wider impact.

This initiative shows how targeted collaboration between technology providers and recyclers can advance circular economic objectives in the heat pump industry. It offers a practical example of turning end-of-life products into valuable resources and supports wider sector efforts towards a circular future. Evaluation of economic and environmental outcomes for this business model is expected to begin in the fourth quarter of 2025, as Alfa Laval and partners further refine and expand their approach. For further details on the business model, challenges, and key stakeholders, please see Annex 3.

7.3. Heat-as-a-service – The case of Vølund Varmeteknik

A common circular business model is offering products "as-a-service" instead of selling the products themselves. This approach has also been explored in the heat pump industry, including in Denmark, where it has been promoted through government subsidies and pilot

testing. Heat-as-a-Service (HaaS) introduces a new way of heat pump ownership, resembling the conditions under which district heating is offered to customers in Denmark [24]. Under this model, customers do not own the heat pump but instead pay for the heat delivered to their homes, while a service provider owns, operates, and maintains the system. This is illustrated in Figure 19.

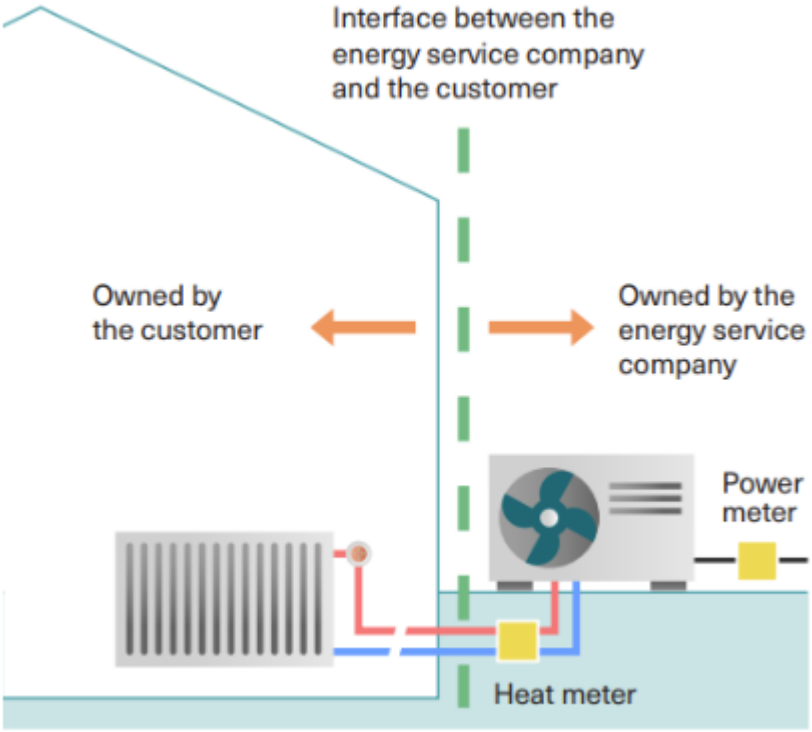


Figure 19: Schematic of the interface between the energy service company and the customer [24].

The Danish government started promoting HaaS in 2016, when the Danish Parliament introduced the concept of heat pumps on subscription as a way to overcome barriers to heat pump adoption, such as high upfront costs and lack of technical knowledge among homeowners. A pilot project was initiated with a budget of DKK 25 million, aiming to install 1,900 heat pumps in single-family homes between 2017 and 2019 [24].

In July 2017, the scheme was expanded to include larger heat pumps for heating and process purposes in businesses, rental properties, and public buildings. However, the focus of the initial pilot project remained on single-family homes. Due to delays in developing business cases and engaging potential customers, the pilot project's timeline was extended to the end of 2020. By the project's conclusion, 885 heat pumps were installed - less than half of the original target - but valuable insights were gained regarding the development of durable business models for HaaS [24].

Building on the lessons from the pilot project, a new, more permanent HaaS scheme was launched as part of the Danish Climate Agreement for Energy and Industry in June 2020. This scheme focused on replacing both oil and gas boilers in areas outside district heating networks. It introduced a pre-qualification process for energy service companies to ensure that participating firms had the necessary expertise and financial capacity to install and maintain heat pumps. The scheme also aimed to encourage competition among providers to create better and more affordable subscription solutions for homeowners. By 2021, five companies, including three from the pilot project, had been pre-qualified under the new scheme [24].

One of the companies in Denmark that offers heat-as-a-service is Vølund Varmeteknik in partnership with OK a.m.b.a, which demonstrates a practical approach to integrating circular

economy principles in the heat pump sector. Instead of selling heat pumps directly to consumers, the model enables end users to pay for heat as a service, with OK retaining ownership and responsibility for installation, operation, and maintenance. When a contract ends before the heat pump's life cycle is completed, the equipment is reclaimed, refurbished, and redeployed, supporting the reuse of products and reducing resource consumption.

Key strengths of this model include making heat pumps more accessible by reducing upfront costs for consumers and extending product lifespans through systematic refurbishment. There are, however, also challenges such as ensuring cost competitiveness over the product’s life cycle and addressing the financial risks associated with third-party ownership and significant initial investment. Early evidence suggests that the number of heat pumps effectively reused and given a second life is increasing, pointing to promising environmental and economic benefits. The offering is described in more detail in a case description in Appendix 4.

8. Conclusions

This Task 2 report has moved beyond the foundational concepts explored in Task 1, investigating the state-of-the-art of practical implementation of circular economy principles within the heat pump sector. The case studies and projects presented reveal that while the industry is in the early stages of this transition, tangible and diverse initiatives are already underway, offering valuable insights for future development.

The investigation into take-back strategies highlights a variety of emerging models. The Swiss system demonstrates a comprehensive, nationwide approach funded by an advance recycling fee, ensuring broad market coverage. In contrast, company-led initiatives like the Danfoss pilot for radiator thermostats and the Grundfos collaboration with NIBE on remanufactured circulator pumps showcase how targeted efforts can prove the viability of component reuse and material recovery. The case of Erion in Italy underscores a significant challenge in the form of informal scrap markets, while pointing to solutions like the "Exceed Clima" programme that build stronger, more formal collection networks. Furthermore, the master thesis with Viessmann suggests that practical models like bulk collection at installer premises may offer a scalable and economically feasible starting point.

Current research projects confirm that industry leaders are actively seeking to embed circularity into their operations. The CE-RISE project, with Viessmann’s participation, illustrates the critical role of digital tools like the Digital Product Passport in achieving material transparency and enabling data-driven decisions for reuse and recycling. Similarly, the Smart-Pumps and the Daikin-led PhD projects show a commitment to exploring concrete circular design strategies and new business models, moving from theory to applied solutions.

The exploration of circular business models, particularly "Heat-as-a-Service" as demonstrated by Vølund Varmeteknik in Denmark, shows a shift in thinking from product sales to lifetime value. By retaining ownership, service providers can facilitate systematic maintenance, refurbishment, and redeployment of heat pumps, directly closing the product loop.

In summary, the practical examples in this report show that there is no single solution for circularity in the heat pump industry. Instead, progress is being driven by a combination of national policies, manufacturer-led pilots, value chain collaborations, and innovative business models. The common threads across these successful cases are strong stakeholder cooperation, a focus on data and traceability, and a willingness to experiment and adapt. These real-world examples serve as a practical foundation, providing valuable learnings that can guide the sector in scaling its circular economy ambitions.

9. References

[1] Chatham House, “CircularEconomy.earth.” Accessed: Jun. 10, 2025. [Online]. Available: https://circulareconomy.earth/

[2] J. N. Uhrenholt, J. H. Kristensen, M. C. Rincón, S. F. Jensen, and B. V. Waehrens, “Circular economy: Factors affecting the financial performance of product take-back systems,” Feb. 10, 2022, *Elsevier Ltd*. doi: 10.1016/j.jclepro.2021.130319.

[3] P. K. Mallick, K. B. Salling, D. C. A. Pigosso, and T. C. McAloone, “Closing the loop: Establishing reverse logistics for a circular economy, a systematic review,” *J Environ Manage*, vol. 328, p. 117017, 2023, doi: https://doi.org/10.1016/j.jenvman.2022.117017.

[4] P. K. Mallick, K. B. Salling, D. C. A. Pigosso, and T. C. McAloone, “Closing the loop: Establishing reverse logistics for a circular economy, a systematic review,” *J Environ Manage*, vol. 328, p. 117017, 2023, doi: https://doi.org/10.1016/j.jenvman.2022.117017.

[5] C. T. Damborg and R. Jørgensen, “Practitioners guide to take-back systems.” Accessed: May 26, 2025. [Online]. Available: https://www.lulu.com/shop/rasmus-j%C3%B8rgensen-and-christoffer-tange-damborg/practitioners-guide-to-take-back-systems/ebook/product-8467wez.html?page=1&pageSize=4

[6] Stiftung SENS, “Neue, nachhaltige Entsorgungslösung für Wärmepumpen,” Zürich, May 16, 2023. [Online]. Available: www.erecycling.ch/entsorgungspartner/sammelstellen.html

[7] Energiaplus, “Branche führt vorgezogene Recyclinggebühr für Wärmepumpen ein | BFE-Magazin energeiaplus | Energiemagazin des Bundesamtes für Energie.” Accessed: Jun. 10, 2025. [Online]. Available: https://energeiaplus.com/2022/04/28/branche-fuehrt-vorsorgliche-recyclinggebuehr-fuer-waermepumpen-ein/

[8] GebäudeKlima Schweiz (GKS), “Vorgezogener Recyclingbeitrag vRB / Branchenlösung Wärmepumpen.” Accessed: Jun. 10, 2025. [Online]. Available: https://gebaeudeklima-schweiz.ch/de/News/Newsmeldung?newsid=59

[9] Energie-Experten, “Wärmepumpen richtig entsorgen.” Accessed: Jun. 10, 2025. [Online]. Available: https://www.energie-experten.ch/de/wissen/detail/waermepumpen-richtig-entsorgen.html

[10] Suissetec, “Neue, nachhaltige Entsorgungslösung für Wärmepumpen - suissetec.” Accessed: Jun. 10, 2025. [Online]. Available: https://suissetec.ch/de/news-detail/neue-nachhaltige-entsorgungsloesung-fuer-waermepumpen.html

[11] V. Berrio, C. Laurent-Dewaele, and L. Roux, “Equipements électriques et électroniques : données 2023,” May 2025. Accessed: Sep. 01, 2025. [Online]. Available: https://librairie.ademe.fr/economie-circulaire-et-dechets/8255-equipements-electriques-et-electroniques-donnees-2023-9791029723308.html#

[12] A. N. Ladegaard and A. V. P. Linder, “Designing take-back systems to improve the circularity of existing and future heating systems,” Technical University of Denmark, 2023. Accessed: Jul. 02, 2025. [Online]. Available: https://findit.dtu.dk/en/catalog/64af410b45c35f915230404f

[13] “BMUKN: The National Circular Economy Strategy (NCES).” Accessed: Sep. 11, 2025. [Online]. Available: https://www.bundesumweltministerium.de/en/topics/circular-economy/circular-economy-strategy

[14] BMWK, “Förderbekanntmachung zur angewandten Energieforschung im Rahmen des 8. Energieforschungsprogramms.” Accessed: Mar. 12, 2025. [Online]. Available: https://www.bmwk.de/Redaktion/DE/Publikationen/Energie/20240531-energieforschung-im-rahmen-des-8-energieforschungsprogramms.html

[15] European Environment Agency, “National circular economy policies | Circularity Metrics Lab.” Accessed: Mar. 10, 2025. [Online]. Available: https://www.eea.europa.eu/en/circularity/thematic-metrics/enabling/national-circular-economy-policies?activeTab=21dbd1ff-0d52-4c5b-92e4-3d0be1954f78

[16] C. Vering *et al.*, “The environmental performance of nationwide heat pump deployment in residential buildings in Germany,” *Cell Reports Sustainability*, p. 100461, Aug. 2025, doi: 10.1016/J.CRSUS.2025.100461.

[17] European Environment Agency, “Europe’s circular economy in facts and figures.” Accessed: Sep. 12, 2025. [Online]. Available: https://www.eea.europa.eu/en/analysis/publications/europes-circular-economy-in-facts

[18] Andrew Keys (Circle Economy), Ana Birliga Sutherland (Circle Economy), Jana Rué Glutting (Circle Economy), and Megan Murdie (Circle Economy), “CIRCULARITY GAP REPORT,” 2023. Accessed: Mar. 19, 2025. [Online]. Available: https://www.circularity-gap.world/denmark
[19] Circle Economy, “CGR 2023.” Accessed: Mar. 19, 2025. [Online]. Available: https://www.circularity-gap.world/2023
[20] European Commission, “Circular Economy Act - Have your say .” Accessed: Sep. 12, 2025. [Online]. Available: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/14812-Circular-Economy-Act_en
[21] European Commission, “The Clean Industrial Deal: A joint roadmap for competitiveness and decarbonisation ,” 2025. Accessed: Jul. 04, 2025. [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52025DC0085
[22] Eurovent, “Eurovent Position Paper - Eurovent comments on GWP calculation for space heaters.” Accessed: Jul. 04, 2025. [Online]. Available: www.eurovent.eu
[23] M. P. P. ; Pieroni, T. Jensen, ; Hjort, D. C. A. ; Pigosso, and T. C. Mcaloone, “Circular Economy Business Modelling: CIRCit Workbook 2”.
[24] Danish Energy Agency, “Heat as a Service Evaluation of a Danish support scheme for dissemination of a new business concept for heat pumps,” 2021. Accessed: Jul. 04, 2025. [Online]. Available: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwjz29PC8aKOAxX5BdsEHRFfMmoQFnoECBYQAQ&url=https%3A%2F%2Fens.dk%2Fmedia%2F6411%2Fdownload&usg=AOvVaw3lR1iGKo9CnqObm3znR7AH&opi=89978449
[25] A. N. Ladegaard and A. V. P. Linder, “Designing take-back systems to improve the circularity of existing and future heating systems,” Technical University of Denmark, 2023. Accessed: Jul. 02, 2025. [Online]. Available: https://findit.dtu.dk/en/catalog/64af410b45c35f915230404f

10. Appendix 1 - Take-back strategy for radiator thermostat

Company information	**Company:** Danfoss **Country:** Denmark
Take-back strategies	Danfoss has introduced a pilot take-back system for radiator thermostats as part of a pilot project in Denmark, in collaboration with a distributor. Installers are encouraged to collect used radiator thermostats from end users and return them to dedicated collection points at selected stores. After collection, the radiator thermostats are transferred through a reverse logistics process, which includes pre-sorting, disassembly, and material sorting. The main focus is on recovering high-quality ABS plastic from the returned products for regrinding. The recycled ABS is then used to manufacture prototype thermostats, demonstrating the practical potential of closed-loop recycling. Danfoss is currently evaluating potentials and feasibility of expanding the takeback project to, e.g., increase the number of collection points and recycle more types of plastic from used radiator thermostats into new radiator thermostats. Danfoss also explores ways to improve logistics and reduce costs as the program grows, aiming to establish a robust model useful in other markets and across a broader product range.
Motivation	Danfoss's motivation for establishing the take-back system is rooted in its commitment to sustainability, resource efficiency, and leadership in circular economy practices. By enabling the collection and recycling of used radiator thermostats, Danfoss aims to significantly reduce waste and lower the environmental impact associated with raw material extraction and product disposal. The initiative supports the company's broader goal of integrating circularity into its business operations and product development processes. Additionally, this system allows Danfoss to demonstrate practical leadership in sustainable product design, helping to set industry standards for responsible end-of-life management. By closing the materials loop and using recycled plastics in new products, Danfoss not only conserves resources but also showcases how circular approaches can be successfully implemented in real-world settings. This approach aligns with Danfoss's ambition to meet ambitious circularity targets and to encourage industry-wide adoption of similar practices.
Key stakeholders	• **Wholesaler:** Acts as the collection point and motivates installers to return used thermostats. • **Installers:** Return used thermostats to collection points. • **Danfoss:** Manages the programme, performs disassembly, sorting, quality testing, and integrates recycled material into new products.
Challenges and barriers	• **Logistics:** Optimization of logistics for collection, sorting, and transport is a current focus. • **Regulation:** Cross-border transport of waste and end-of-life products

	presents regulatory challenges. • **Market and Scale:** Scaling up from pilot to full implementation and expanding to other brands and countries are open questions.

Impact assessment	• **Carbon Footprint:**
	  ○ Recycling ABS and PBT plastics can reduce the carbon footprint of the radiator thermostat by up to 23%.
	  ▪ 13% by recycling ABS only.
	• **Quantitative Tools:**
	  ○ Danfoss uses internal tools like RE:CIRC to assess and track circularity and sustainability of products.

Contact information	**Name:** Gitte Tang Kristensen **Organization:** Danfoss **Phone number:** +45 5236 6069 **Email:** gtang@danfoss.com
Additional information	• **Tool Integration:** Circularity tools and sustainability assessments are now integrated into all new product development projects at Danfoss.
Date	13-05-2025

11. Appendix 2 – ebm papst– take-back strategies for heat pumps and their parts

Company information	**Company:** ebm-papst **Country:** Germany
Take-back strategies	ebm-papst is currently developing concepts for the take-back and recovery of heat pump components such as fans, motors, and electronics. Plans include: • Exploring collaborations with OEMs and service partners for end-of-life collection. • Assessing reverse logistics options for selected parts. • Investigating the use of digital identifiers to enable tracking and support disassembly. • Reviewing design principles to improve recyclability and facilitate dismantling. These activities are in the early planning and evaluation phase.
Motivation	The initiative is driven by: • Anticipated regulatory developments (e.g., ESPR, WEEE). • Interest in reducing material waste and recovering critical resources. • Growing customer expectations around product responsibility. • Support for long-term goals in circular business model innovation.
Key stakeholders	Potential partners include: • Heat pump OEMs • Service and maintenance providers • Recyclers and logistics companies • Industry associations and regulators Roles (to be defined): • ebm-papst would lead on component design and coordination, while partners would support collection, dismantling, and material recovery.
Challenges and barriers	• Limited design standardization for easy disassembly. • Lack of established take-back infrastructure. • Economic uncertainties around recycling low-value components.
Impact assessment	Expected benefits (under evaluation): • Reduced waste through component reuse or recycling. • CO_2 savings via extended product and material life.

	Potential KPIs (under evaluation): • Volume of parts collected and processed. • Recovery rates for key materials (e.g., copper, aluminum).
Contact information	**Name:** Pascal Köhler **Organization:** ebm-papst neo GmbH & Co. KG **Email:** pascal.koehler@epneo.com
Date	25.07.25

12. Appendix 3 – Alfa Laval – Business model for heat pumps and their parts

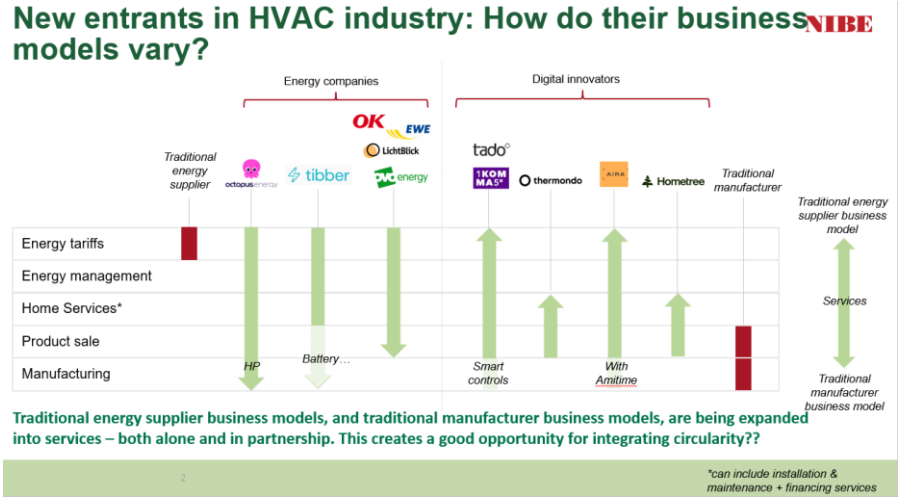
Company information	*Company:* Alfa Laval *Country:* Sweden
Business model	*Describe the business model practices being implemented, such as product-as-a-service models, leasing, remanufacturing, or component reuse* When it comes to our climate challenge, there are no quick or one-size-fits-all-solutions – especially not in the industrial sector. We all need to take care of our natural resources. This includes the physical materials we use but also optimizing our use of energy through improved efficiency. Every kW we can save will matter. Everything that can be done in a better way must be done. From big structural changes and great innovations to small improvements and minor adjustments, every step in the right direction is an important piece of the puzzle. It's about working together to accelerate the transition towards a carbon neutral and circular future. And that's exactly what the partnership between Stena Recycling and Alfa Laval is all about. We call it Re-Made to matter. The core of this partnership is a business model for heat exchangers that have reached the end of their lifecycle or are no longer efficient. Our customers will be able to order a new, state-of-the-art Alfa Laval brazed heat exchanger and the old unit will then be sent to our partners at Stena Recycling, who will recycle it to recover up to 100% of the valuable metals inside." The main purpose of this business model is to recover value from old unis instead of treating them as waste. The Value Proposition can be so listed: 1) Sustainability Value: recovery of Stainless Steel and Copper, reducing the environmental impact 2) Performance Value: Customers can upgrade new, more energy-efficient exchangers by cutting operating costs and CO2 emissions.
Motivation	*Describe the motivation for establishing the new business model.* There is no quick fix in the transition to a carbon neutral and circular future. Fortunately, Alfa Laval and Stena Recycling have been working together to come up with a smart, sustainable and easy-to-use solution. This exchange program will make it possible to recover as much as 100% of the valuable metals found in old heat exchangers. That

	means that we can protect the environment and reduce the use of virgin materials in our own production. The environmental benefits extend even further when you switch to modern, more thermally efficient heat exchangers in your process. You will see an immediate improvement in your energy efficiency, while cutting power costs and reducing your CO2 footprint. In this way, we are working together to decarbonize our industry. Alfa Laval's innovative heat exchanger technology will significantly increase the energy efficiency of our customer processes. That means drastically lower power consumption and carbon emissions, along with a significant reduction in customer long-term operating costs. In other words, it's a classic win-win-win situation.
Key stakeholders	• Alfa Laval – offering and providing take-back programs for old units • Recycling facilities for metals – disassembling and separating metals as well as organizing collections of old heat exchangers • Logistics providers for reverse supply chain – provide traceability as well as moving heat exchangers to recycling facilities • Heat Pump Manufactures with take-back contracts – return heat exchangers at the end of life instead of scrapping them. • End-Users.
Challenges and barriers	*Highlight any identified barriers to implementing circular practices, such as regulatory challenges, market acceptance, or technical limitations.* Technical Challenges: • Limited advanced recycling technologies for brazed copper and stainless steel • Different metal quality between EU and EX EU • Uncomplete knowledge on different separation technologies among EU and not EU, and the CO2/environmental impact. Market Acceptance: • Missing incentive schemes and clear regulatory landscape • No concrete requests received before 2025 Logistic Barriers: • No existing supply chain between component manufacturers and final end-users. Regulatory Challenges: • Overseas suppliers for some components may require a global partnership

	• CBAM implementation
Impact assessment	*Economic impact: Evaluation of business impacts (e.g., cost savings or new revenue streams).* *Measurable outcomes: If possible, please share any indicators or methods used to evaluate the effectiveness of circular practices. Examples could include cost savings, or other measurable benefits.* We will start to evaluate both the economic impact and measurable outcomes starting from Q4-2025.
Contact information	*Name/organization:* Olle Esser / Product management Sara Billo and Benedetta Copertaro / BU BFB Sustainability Department Stefano Bissoli / Global KAM Silvia Fava / Application Product Specialist *Email:* sara.billo@alfalaval.com; benedetta.copertaro@alfalaval.com; olle.esser@alfalaval.com; stefano.bissoli@alfalaval.com; silvia.fava@alfalaval.com
Additional information	*If relevant additional inputs/figures can be given here to elaborate on the case.* *Starting from Q4-2025, in BU BFB we will start to work on an improved recycling business model.*
Date	*Please put in date for filling out this template.* 29/08/2025

13. Appendix 4 - Vølund – Heat-as-a-service

Company information	**Company:** Vølund Varmeteknik A/S **Country:** Denmark
Business model	Vølund Varmeteknik is a supplier to the Danish energy group OK a.m.b.a of a solution consisting of high-end AWHP and associated indoor unit. OK stands for agreement and installation at the end user, as well as maintaining efficient operation. The end user is charged based on produced kWh heat and domestic hot water. The business model is based on a long-term agreement between the end user and OK, but if the end user terminates the agreement before the heat pump's life cycle has come to an end, the heat pump will be reclaimed and sent for restoration and facelift at Vølund, after which it will be reinstalled with a new end user. The solution is throughout the process from sale from Vølund owned by OK a.m.b.a
Motivation	The business model has been developed based on a plan from the Danish goverment to promote the spread of heat pumps to replace individual oil and gas boilers. On this basis, a number of installation companies were pre-qualified to receive subsidies for the dissemination of HaaS. OK is one of the companies that has had the most success with the concept and their business plan with their Vølund solution.
Key stakeholders	**Involved Parties:** NIBE/Vølund, OK a.m.b.a and Enduser. **Roles and Responsibilities:** Vølund starts up and adjusts after installation and provides a 5-year extended warranty on the solution. Performs restoration and facelift as needed through reuse at another address. OK ensures optimal operation during the contract period with the end user and conducts annual service inspections through a partner with the right knowledge and qualifications.
Challenges and barriers (some are abroad but not I DK)	• that over the lifetime it can be more expensive for the consumer than buying upfront • that many companies start up with 'full HaaS' where the customer pays a fixed monthly fee for the heat, but the risks are too great for the service provider so in the end these models are scaled back to more simple lease or other financing models (e.g. Eneco in NL had a "comfort as a service" model which they dropped; Viessmann offered HaaS but scaled it back to leasing…). • that the business models sometimes rely on (unsustainable) subsidies • that 3rd party ownership of the HP is often not possible while still making use of subsidies (see UK Boiler upgrade scheme, or Thermondo in Germany having to change their model) • That the service provider needs a big investment upfront – OK have been able to do this themselves. Perhaps things like Asset Backed Securitization can help smaller companies be able to offer financing
Impact	**Economic impact:** No knowledge of that part.

assessment	**Measurable outcomes:** The numbers of refurbished heatpump living their 'second' live is increasing in OK's Haas.
Contact information	**Name:** Per Thomsen **Organization:** Vølund Varmeteknik **Phone number:** +45 2448 8886 **Email:** pt@volundvt.dk
Additional information	
Date	June 18th 2025.

Heat Pump Centre
c/o RISE - Research Institutes of Sweden PO Box 857
SE-501 15 BORÅS
Sweden
Tel: +46 10 516 53 42
E-mail: hpc@heatpumpcentre.org

www.heatpumpingtechnologies.org

Report no. HPT-ANXX-1