Towards advanced circularity in Bornholm - The implementation of 9R model in a take-back system for heat pumps

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Abstract:

The Master's Thesis sheds light on the heat pump sector of Europe, in relation to their end-of-life waste management and circular practices integration. Through research, this project deep dives into the case of the Danish island of Bornholm and focuses on the co-design of an advanced take-back system for heat pumps, with the contribution of involved stakeholders.
Utilizing the Design-Based Research method and having a stakeholder-driven approach, several opportunities and gaps were identified in comparison to the future planning of the design, use, and disposal of heat pumps. The potentials of the 9R circular framework are highlighted in the process, justifying the solidity of circularity in waste management, while maintaining value in the system.
There is also a focus in the perspective of innovation and the importance of facing the challenge of heat pump management with the more circular, based on eco-desing and innovation pathway. The co-design of take-back system can contribute to similar small-scale communities with further investigation and testing of the system.

Paraskevi Striga

Preface

This is a 30 ECTS point Master's thesis on the fourth semester of the master's degree Sustainable Cities at Aalborg University in Copenhagen. The project has been prepared in the period from 1st of February 2025 to the 28th of May 2025.

In this project it is examined how the circular economy practices can be implemented in the heat pump sector, in particular to a take-back system for heat pumps in order to facilitate the transition to circular economy in Bornholm. There is also a focus on the Eco-innovation of a circular economy system, such as an advanced take-back system.

Thank you to my supervisor Johannes Cornelius Brezet, and thanks to the very accommodating and helpful interviewees:

- David Christensen, team leader (Projects) at BOFA
- Anine Selander, project manager at BOFA
- João Møller, project manager in BEOF
- Marcus Hansen, installer, Flemming Svendsen VVS
- Nadine Haxgart, intern in A&O Johansen
- Ebba Fjelkner, business engineer in Alfa Laval
- Jean-Charles Willm, Eco-design adviser in BDR Thermea

It was of great importance for their participation in this project, because it improves understanding of the landscape of the heat pump sector and the development of circular practices.

Reading guide

This project is structured according to academic standards and includes an initial exploration of the problem area, a defined problem statement, a theoretical framework and methodology, as well as analysis, discussion, and conclusion.

The introduction is presented in section 1, leading to the chapter problem analysis 2. This chapter explores the challenges related to heat pump sector, in particular about their waste management in Denmark and draws attention to the current situation in Bornholm. The problem definition follows after the problem analysis in Chapter 3, which lays the foundation for the project's analysis. Chapters 4 and 5 present the theoretical framework and methodology of problem definition, which subsequently results in analysis and discussion in Chapters 6 and 7, which leads to the conclusion, in Chapter 8. [1]

[1] In parts of this Master's Thesis report simple AI, ChatBot GPT, has been consulted for the following general assistance: 1)optimizing translations (Chapter 2 & 4), 2)checking text summaries on their completeness and accuratesse (Chapter 7 & 8, and 3)controlling language and condense texts (Chapter 2, 4, & 5) All following the guidelines from the exam regulations and guidelines.

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Introduction

The international challenge for a change towards energy-efficient, environmentally friendly energy systems has drawn attention to technologies that are low in environmental impact and energy-efficient. Heat pump production started to increase, due to their technological ability to offer more efficient heating and cooling option than traditional systems. As the European Union (EU) increasingly accelerates its climate and energy policy, heat pumps are increasingly renowned for their capability to reduce energy consumption, lower greenhouse gas emissions, and optimize the utilization of renewable sources of energy. However, with rising use in residential and commercial markets, the lifecycle management of heat pumps is an excellent and previously neglected challenge.

Contemporary manufacturing and waste treatment practices for heat pumps normally follow a linear "take-make-dispose"approach, which is inadvertently counter to sustainability principles. In addition to simply creating additional waste, taking the linear route continues the loss of important materials and components that can further impact the environment. Circular Economy (CE) practices are an innovative alternative with the principle to take an approach focused on strategies for reuse, repair, refurbishment, and recycling. CE strategies mitigate waste work towards closed-loop systems which contribute to the long-term sustainability of the environmental, economical, and social integrity surrounding the creation, use, and disposal of products at the end of their life.

The emphasis of this project is the Danish island of Bornholm, recognized for being a leader in circular economy initiatives and sustainable innovation. Bornholm's ambitious target to be a zero-waste island by 2032 is firmly in line with the EU's broader CE strategy, and it is therefore a strategic case study for the investigation of the application of circular methods to the lifecycle management of heat pumps. While Bornholm has made widespread advances in sustainability across many spheres, there is no defined approach to the end-of-life phase of heat pumps, a vital blank space. This project attempts to bridge that gap by exploring how circular solutions can be effectively integrated into an in-place take-back system.

This master thesis created at first as a part of the NESSIE EU Interreg project, which aimed at developing a Short Advanced Courses for installers and other intermediaries in the E-transition. Specifically, NESSIE aims to promote and accelerate the stimulation and diffusion of fitted practices Innovative Energy Equipment in and for individual homes through new knowledge, upgrading, and returning to the existed knowledge by E-Intermediaries for effective and efficient communication.

Problem analysis

The growing interest in sustainable energy solutions propelled by continuing international energy issues, has also positioned heat pumps in a stronger position with the movements toward cleaner energy systems. Within Europe, a growing trend is for residents to utilize home heat pump. This is facilitated by national agencies and international campaigns engaged by the European Union. Although the various "heat pump"initiatives promote the devices, an overall life cycle impact and inclusion within circular economy models is a significant gap.(EHPA, 2024).

The heat pump industry also operates within a linear production and consumption model called "take-make-dispose", which neglects environmental concerns since it emits greenhouse gases and depletes finite resources like fossil fuels. The circular economy model offers up a more sustainable alternative, but in contradiction it does this by prioritizing their reuse and also the recycling of materials and the design for circularity of products. This approach helps in order to reduce climate change, it reduces reliance upon nonrenewable resources, and it responds to more broader global pressures such as population growth with international competition(Pichlak M. Szromek A., 2022).

2.1 The current situation

Heat pump technology has exhibited global growth momentum because of an increase in sales in 2022 by roughly 11% compared to 2021. The European Union was ahead of the curve with a 33.8% increase in sales. The growth did continue, for heat pumps the EU was the fastest growing global market (International Energy Agency, 2022). Heat pumps are also recognized for their energy efficiencies and environmental benefits and, therefore, are more sustainable alternatives to conventional forms of heating (gas or oil-burning boiler units) and also capitalize on energy and climate targets in the EU (Naumann, G., et al., 2022).

The rapid increase in the utilization of heat pumps is of vital strategic importance in meeting the EU's energy reduction and carbon reduction targets, especially in residential and commercial heating and cooling systems. Their benefits are accentuated further as renewable energy sources are more broadly integrated into EU member states. This, in turn, complements the EU's wider energy goals and commitments towards renewable energy (European Commission, 2022). In addition, heat pumps facilitate the EU's transition from the linear economy to a circular economy since they are designed to be durable and require minimum maintenance; thereby, contributing to longer product life cycles and a reduced consumption of resources. Durability and repairability may be the two of the most important values that the design phase may be able to implement towards making a circular economy happen (European Commission, 2022).

According to data from early 2022 compiled by EHPA in 16 European nations, heat pump sales experienced a 38% increase yearly, exceeding the 34% growth observed in 2021. To date, approximately 20 million heating heat pumps have been installed throughout Europe. These include air-to-air, hydronic (water-based) and hot-water systems, which now supply heating to roughly 16% of residential and commercial buildings of the continent (EHPA, 2023*b*).

In 2023, heat pump sales in 21 European countries reached 3.02 million units, increasing the total number of installed systems to approximately 24 million. The sector now includes over 250 manufacturing facilities across Europe and represents an estimated €7 billion in investments between 2022 and 2025. It also provides direct employment for around 168,000 people (EHPA, 2023*a*).

While the demonstrated growth is indicative of the growing salience of heat pumps as a result of their efficiency and overall energy performance, it is equally a signal for an increase in future end-of-life equipment. Still, current practices often focus on increased production and not next steps for managing these systems in accordance with principles of sustainability and circular economy after their end-of-life.

Furthermore, the consumption of electrical and electronic equipment in Denmark exceeds the EU average in terms of WEEE generated per capita. To support the collection of WEEE, Denmark's Environmental Protection Act introduced an Extended Producer Responsibility (EPR) framework (Circle Economy, 2023).

In 2022, the generation of waste related to electrical and electronic equipment designed for temperature exchange was approximately 23,000 tons. Of this amount, 16,130 tons were collected, while according to Eurostat, 12,287 tons were recycled. In contrast, only 338 tons were prepared for reuse (Eurostat, 2025).

In 2023, according to the DPA (DPA, 2025), the temperature exchange equipment (including heat pumps) placed on the Danish market were 31,874 tons in total, while the number of the same equipment collected was 16,035 tons in total (DPA, 2025). Data were collected in annual reports from EEE producers and importers in Denmark, which is overseen by DPA (DPA, 2025).

From a research perspective, the Danish Technological Institute has an ongoing project that focuses on heat pumps in the circular economy and what their possibilities are. They are collaborating with partners from different sectors, and their main focus is a forum where they provide the status of heat pumps from the lenses of the circular economy (Danish Technological Institute, 2024). The status of the project is still in the early stage, while the partners are collaborating on creating a center of knowledge to provide data and information for potential users that are interested in the implementation of circularity in heat pumps (Danish Technological Institute, 2024).

In general, much attention has not been paid in research on the way heat pumps are managed when they become waste from a circular perspective. Although heat pumps are considered electronic as well as electric devices and certified experts are responsible for managing them, there are regulations from the Danish law and directives from the EU that make the development of different projects.

2.2 Legislation and regulations on heat pumps

This project aims to illustrate the whole landscape around heat pumps in Europe and Denmark by looking into the regulations and action plans surrounding heat pumps. In addition, it will also look into the essential actions put forth in the circular economy's incorporation, and that the EU's goals will enforce.

2.2.1 The EU Circular Economy Action Plan

Implemented in 2020, the EU Circular Economy Action Plan seeks to transition the EU away from a linear economy that continues to follow the take-make-dispose way of thinking; instead taking us toward a circular economy that focuses on closed loops for products and materials. The Plan is also part of the European Green Deal and promotes the notion of design things for longevity, resilience, durability, and reusable. A primary scope of the Plan is to address material scarcity and waste volumes (European Commission, 2024*a*).

Part of the EU Circular Economy Action Plan is innovation funding and support for small businesses in the EU that aim to propose solutions in the market. Through the LIFE and Horizon Europe program funding, the EU supports the initiatives that develop circular applications from businesses and organizations and use digital tools to achieve circular objectives (European Commission, 2020).

In addition, the EU has recognized the circularity aspect in relation to climate neutralization, as enabling long-term competitiveness for business - and the transition to circularity, while it will have a positive environmental consequence - will yield economic value and innovation along value chains in the EU Market. The European Commission is offering a direction for circular economy in their EU SME Strategy by reformulating and reiterated some points, including embedding circularity practices, building a better reporting and certification system and incorporation of digital technologies. Importantly, this includes SMEs as part of the circular economy scope of the EU (European Commission, 2020).

Given how heating and cooling systems are a significant source of energy consumption in Europe, and the reliance of heat pumps on critical raw materials, there are a great many possibilities to address circularity from an environmental and economic value perspective in relation to this sector.

2.2.2 Denmark's Action Plan for Circular Economy

Denmark's Action Plan for Circular Economy acts as the country's national strategy for waste prevention and management from 2020 to 2032. In a circular economy, products and materials are kept in use for as long as possible to maintain their value. The Action Plan emphasizes national goals, policies, indicators, and initiatives covering the entire value chain, from product design to waste management (Ministry of Environment of Denmark, 2021).

The Action Plan targets several key areas, including waste reduction, improved management of natural resources, and enhancing recycling processes. Denmark's shift toward a circular economy is driven by its high natural resource consumption that equals to 23 tonnes per capita per year, which surpasses the global average of overconsumption, at around 15 tonnes per capita (Ministry of Environment of Denmark, 2021).

This paper aligns perfectly with the Circular Economy Action Plan regarding the measures that need to be undertaken for the whole life cycle of heat pumps. On the one hand, the measures have to do with the production and consumption of the pumps. On the other hand, they also have to do with the most crucial phases of the heat pumps, the disposal and recycling phases.

Denmark has established a large subsidy program to increase heat pump adoption in Denmark that aims to transition households away from fossil fuel heating systems to cleaner alternatives. The primary objective is to lessen reliance on natural gas and other fossil fuels will lead to decreased greenhouse gas emissions, and support the country in achieving its climate goals. The Danish government in 2022 had aimed to halve existing natural gas heat for domestic heating to district heating by 2028, along with a significant ramp up of heat pump installations across residential and district heating networks (University of Cambridge, 2022). Currently, almost 66% of homes in Denmark are connected to district heating, which relies on biomass and partly on waste heat while over 80% of the power in Denmark is produced with renewable energy resources, especially wind, biomass and solar. (International Energy Agency , 2023).

2.2.3 WEEE Directive

The WEEE directive (Directive on Waste Electrical and Electronic Equipment) emphasizes the minimization of the environmental effects of electronic and electrical waste. Heat pumps fall within the scope of the WEEE directive, and their collection, recycling and recovery are carried out according to specific standards at the end of their life cycle (EU, 2024).

The WEEE directive was passed into law by the Danish government in 2006 and in February 2014 began to be integrated into national legislation (Ministry of Environment of Denmark, 2024).

In Europe there are projected to be increases in WEEE by 3-5 % every year; heat pumps will be a considerable contributor to this rise. The European WEEE directive has set the target of recycling 4 kg of EEE per person; this target cannot help but fall short in enabling sustainability given the increased growth in the production of electrical and electronic equipment (EEE) (Hischier, R., Wäger,P. and Gauglhofer,J., 2005).

The WEEE directive is a tool for businesses associated with the heat pumps sector that aspires to the management of the electronic part of the heat pump. Despite the fact that it incorporates the necessary steps for the suitable disposal of the electronic and electrical part of a heat pump, the WEEE directive does not include the disposal of the remaining elements of a heat pump, which are the metal or plastic casing of the heat pump and pipes, coils and insulation.

2.2.4 REPowerEU

Additionally, the European Commission has launched the REPowerEU plan, which supports the objectives of the EU Green Deal by focusing on three key areas: improving energy efficiency, diversifying energy sources, and increasing the generation of clean energy (European Commission, 2024*d*). The REPowerEU plan has also established targets for heat pumps, with their main focus being on doubling annual deployment rate of heat pumps in EU in relation to 2021, increasing the number of hydronic heat pumps in the year 2023 to 2027, and deploying approximately 6 million new heat pumps annually starting from 2025. The European Heat Pump Association (EHPA) estimates that if these goals are met, the total number of heat pump installations in the EU could reach 60 million by 2030 (Adamo, A., et al., 2024).

At the national level, the Danish Government and Danish Energy Agency, supported by the Horizon Europe Program (HEP), have financed and currently are financing projects focused on heat pumps and incorporation into energy systems in Denmark (Adamo, A., et al., 2024). This whole initiative also shows the urgency from the sector to make the transition now, especially considering that Denmark has made a commitment to reduce CO2 emissions by 70%, with 25% through electrification and heat pumps (Adamo, A., et al., 2024).

2.2.5 Critical Raw Materials Act (CRMA)

Heat pumps are integral to the EU's decarbonization goals, because of their high efficiency, while their production relies on several critical raw materials, such as rare-earth elements (neodymium, praseodymium, and dysprosium), copper, aluminium, and F-gases (Baldassarre, B., & Carrara, S. , 2025). The European Union's Critical Raw Material Act (CRMA) is the legislative framework for the dependency of EU on non-EU countries for key raw materials, that are used in energy technologies, like heat pumps. At the rising of the demand for such products, the urgency to secure access to these materials is also rising. The CRMA highlights the vulnerability of current supply chains, where a significant proportion of raw materials is imported from a single country, often under conditions that are economically or geopolitically unstable (European Commission , 2025).

In order to mitigate the supply risks and sustainability in the heat pump sector, the EU has initiated a plan based on the critical raw material supply in the European market, as well as the processing and recycling of these materials (Baldassarre, B., & Carrara, S. , 2025). The supply targets that have been set aim to increase the extraction and processing of strategic raw materials within the borders of the EU, to increase the percentage of recycled materials, and to decrease the percentage of the consumption of the materials from a single third country (Baldassarre, B., & Carrara, S. , 2025).

These regulations affect the heat pump sector and have several implications for stakeholders within this sector. For manufacturers, the design of heat pumps should aim to be easier to recycle and make use of less CRMs, while for manufacturers that have higher dependency on single suppliers or countries, they should aim to diversify their supply chain (García-Gusano, D., et al. , 2025). Another implication is the push for the development of recycling technologies to recover CRMs from end-of-life products, and the compliance with EU regulations in order to stay competitive in the market for the most stakeholders (García-Gusano, D., et al. , 2025).

The combination of the action plans between the integration of heat pumps in the energy sector and the circular economy results in several inconsistencies. Some of these arise from inadequate planning for the disposal of a product or the implementation of it in a closed-loop model for heat pumps (Baldassarre, B., & Carrara, S. , 2025).

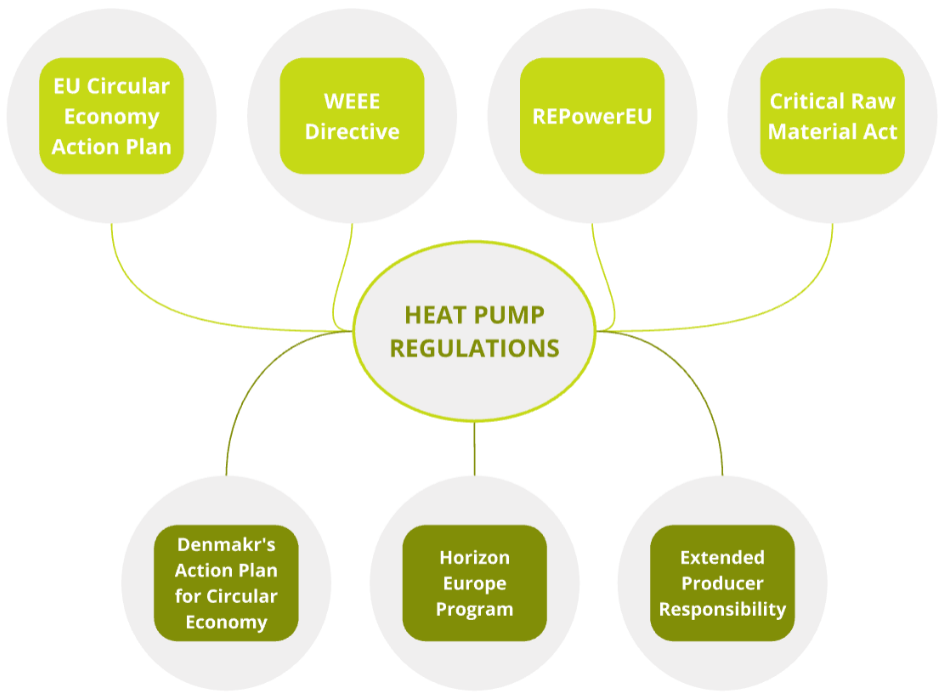


Image 2.1. The European and Danish regulations that affect heat pumps in relation to circular economy (Own figure)

Considering all the European and national legislative initiatives together creates a robust framework that not only promotes the deployment of heat pumps as part of the clean energy transition, but also lays the groundwork for their responsible end-of-life management. The convergence of the EU Circular Economy Action Plan, the WEEE Directive, the REPowerEU strategy, and the Critical Raw Materials Act reflects a broader systemic shift, from isolated climate or waste policies to integrated circular policy-making. This evolving regulatory landscape sets the scene for a more circular heat pump sector by encouraging eco-design, mandating take-back responsibilities, and promoting the recovery and recycling of valuable materials.

These policies act not only as incentives for innovation but also as a call to action for stakeholders to co-develop solutions, such as take-back schemes and repair networks, that address the growing challenge of heat pump waste. By embedding circularity into both policy and practice, the EU is actively planning for a long-term, sustainable system in which heat pumps are not only a solution for decarbonization but also a model for circular product management.

2.3 Eco-design for Sustainable Products Regulation

The Eco-design Sustainable Products Regulation (ESPR) is part of a package of measures that are central to achieving the goals of the 2020 Circular Economy Action Plan and fostering the transition to a circular, sustainable and competitive economy (European Commission, 2024*b*). It is aimed to contribute to helping the EU reach its environmental and climate goals, double its circularity rate of material use, and achieve its energy efficiency targets by 2030 (European Commission, 2024*b*).

The role of regulations such as the ESPR in creating sustainable systems is crucial, especially when considering the life cycle of products such as heat pumps.

ESPR is probably the largest attempt by the European Commission to improve the environmental performance of products throughout their life cycle (from design to disposal). Heat pumps, which are energy-efficient alternatives to conventional heating and cooling systems, could benefit from specific ESPR provisions on energy performance, repairability, and recyclability. The directive shapes the way heat pumps are designed, manufactured, and ultimately recovered. ESPR plays an essential role in the design features of heat pumps (European Commission, 2024*b*).

The directive also enhances EPR (Extended Producer Responsibility), a model where manufacturers are liable for the entire life cycle of the product and to incentivize design features that would extend heat pumps' lifetimes, facilitate reuse and materials recovery(Sakao, T. et al. , 2024). A key feature of ESPR is the upcoming digital product passport, which could transform take-back systems by enabling:

- Identification of product components and materials

- Effective sorting, recycling, and remanufacturing

- Confirmation of producer compliance with take-back responsibilities

For heat pumps this could mean optimizing the recovery of valuable components (compressors, electronics and refrigerants). ESPR can provide market benefits for other companies with take-back systems, that use secondary raw materials, and sell refurbished heat pumps. This would internalize the environmental costs, creating a circumstance for the take-back system from a regulatory burden to a competitive position (Sakao, T. et al. , 2024).

2.4 Bornholm - The case island

Bornholm is a Danish island in the Baltic Sea and has a prominent position in the circular economy (CE) initiatives in Europe. The island has a population of around 40.000 inhabitants over an island total area of $588km^2$ (Christensen, T.B., et al. , 2022). Bornholm is part of the FREIIA (Facilitating Resilience Enhancing Islands Innovation Approaches) project with many islands and is working together to encourage sustainable actions and innovation. In accord with Bornholm Municipality, the target that has been set is to reduce landfill and incineration to virtually zero by 2032 in terms of closed material loops (Dr Cormac Walsh Research and Consulting, 2024). Bornholm works with circular strategies in many different areas to aid its commitments to circular economy (Christensen, T.B., et al. , 2022).

Bornholm works with circular strategies in many different areas to aid its commitments to circular economy (Christensen, D. A. M., et al. , 2021). Several initiatives have been implemented to encourage reuse and recycling of materials - recycled food; resource efficient systems that have reduced waste and improved efficiency (Christensen, D. A. M., et al. , 2021). These strategies will in-lead to the overall plan for Bornholm to eliminate waste entirely by 2032, showing the island's intentions for a sustainable transition (Eastaugh S., 2023).

Through these attempts, Bornholm's commitment to sustainability and innovation makes the island a good model island to be examined regarding the smooth transition from a linear to a circular economy, using different practices and strategies to achieve the goals that Europe has set. Despite the fact that Bornholm plays an important role, there is no plan for the end of life of heat pumps, which is a major inconsistency with their objective of 100% reuse and recycling of waste. The above factors make the island a suitable case study for researching the life cycle of heat pumps and examining the roles of various stakeholders in shaping the current state of heat pump usage there.

While Bornholm seeks to become a zero-waste island by 2032, both on the island and throughout the nation, there is also an emerging movement to facilitate adoption of heat pumps with economic incentives for the customers. Denmark already has expansive subsidy programs related to heat pump adoption, furthering the Danish government's ambitions to reduce greenhouse gas emissions and increase energy efficiency. The Danish Energy Agency provides financial support for households that replace a conventional heating system with a heat pump. Grants are offered to homeowners, DKK 17,000 for air-to-water heat pumps and DKK 27,000 for ground-source (liquid-to-water) heat pumps, specifically those homes not connected to district heating (Danish Energy Agency, 2023). These subsidies are to support the ambition of Denmark's larger aim of 55% renewable energy by 2030 (Jowett, P., 2024).

In Bornholm, these publicly disclosed national economics programs are highly influential. Bornholm's vision of being a sustainable living laboratory aligns closely with the aims of the heat pump programs. By helping residents move from older oil and gas boilers to energy-efficient heat pumps, the program further catalyzed the island's movement away from fossil fuels and toward renewables and toward its zero-waste and carbon-neutral aspirations. The establishment of these funding streams supported heat pumps transitions on the island, and demonstrates how effective funding streams can accelerate the sustainability energy transition at the community level (Jowett, P., 2025).

2.5 Stakeholders

The identified stakeholders in this study play different roles that impact the transition towards a circular economy, and their involvement is equally valuable in the recognition of issues related to heat pumps, addressing issues and advance the development of solutions.

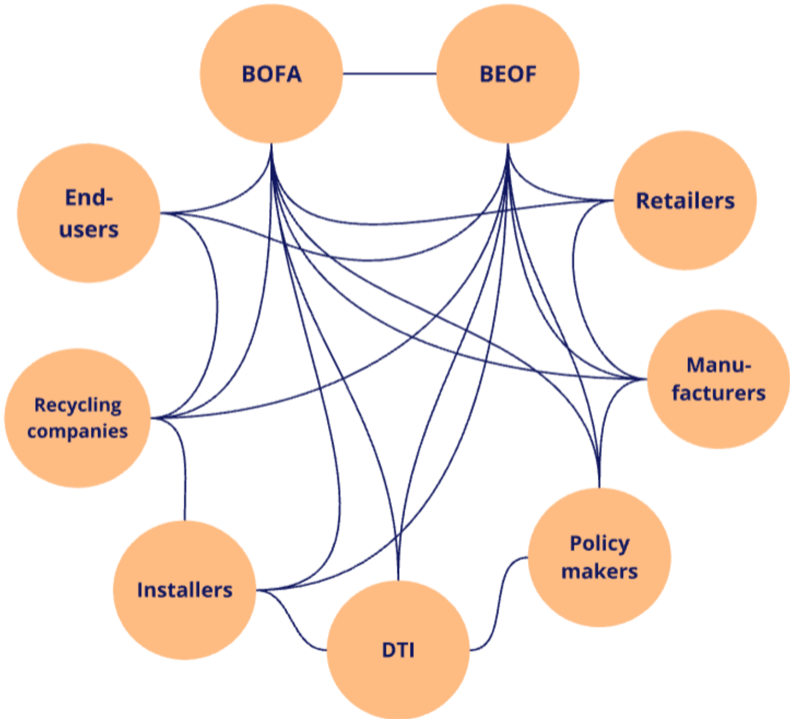


Image 2.2. The map of stakeholders from each stage life of heat pumps (Own figure)

The figure 2.2 shows the visualization of the map of stakeholders associated with the heat pump sector in Bornholm and demonstrates the relationships between them. The connections stem from interviews, research, empirical observation, and logical reasoning.

Producers - manufacturers

Manufacturers are instrumental in determining the materials used in products and how the products are designed, and, as such, have a pivotal role to play in realizing the Eco-design directive, which promotes energy efficiency, durability, ease of repair and reuse, and recyclability. All of these motivations coincide with the notions of circularity, as manufacturers are actively pursuing opportunities to be more efficient in their material usage by focusing on recovering and reusing components and are also redesigning heat pumps to maximize the ease of disassembly.

The indicated manufacturers in this project are Alfa Laval and the BDR Thermea Group. Alfa Laval is a global leader in heat transfer, separation, and fluid handling technologies, they have a large share of the market in HVAC. They provide advanced heat exchanger solutions that enable the effective functioning of residential and commercial heat systems (Alfa Laval, 2025). The company promotes a portfolio of heat pump solutions (from a few kW to more than 800 kW depending on the design and application) to both residential and commercial markets. Additionally, the company plays an important role in the implementation of circular economy principles into the heat pump market, especially as it pertains to material efficiency, product material recycling, and a consideration for the product life cycles. The company continues to execute efforts that limit the use of virgin materials and limit the life cycle emissions of heat pump systems, like cooperating with Stena Recycling, and participating in the 'Re-Made to matter' scheme (Alfa Laval, 2023). Alfa Laval has a solid position in Denmark with its manufacturing plants, as well as its climate-friendly technologies developed within national and European policy frameworks. The company also collaborates with the many local stakeholders - municipalities and district heating operators at this scale - to stimulate the adoption of heat pumps as a component of Denmark's sustainable heating strategy (Alfa Laval, 2025).

BDR Thermea Group is a preeminent manufacturer of intelligent climate solutions and heat pumps, promoting a strong circular economy and sustainability agenda. BDR Thermea Group guides its corporate sustainability initiatives using the "4Hs"heat pumps, hybrids, hydrogen, and heat networks for the energy transition. In the production of heat pumps, the heating capacities could vary between 5 kW or 6kW (BDR Thermea Group, 2024). As a member of the circular economy BDR Thermea Group always works with business practices that extend the life cycle of the product and help reduce environmental impact. Recently BDR Thermea Group has invested its entire supply chain to scale up its heat pump production to meet this new demand for energy-efficient and sustainable heating solutions (BDR Thermea Group, 2025). Their business model is not limited to just refurbishing and recycling components but also designing products to be disassembled and the materials reclaimed which fits the definition of circular economy (BDR Thermea Group, 2024). As part of their commitment to the energy transition, BDR Thermea Group is also reskilling installers and training them to support sustainable climate solutions across Europe, including Denmark. They also ensure they provide installer support through their in-house training centres, remote assistance and help with subsidy applications to ensure their products are innovative, easy to access and maintain (BDR Thermea Group, 2025).

In Denmark, BDR Thermea supports national and European regulation by encouraging energy efficient solutions and training their installers to apply sustainable solutions as they come in. Through its initiatives, the company is contributing to the carbon-reduction goals of Denmark - which are also aligned to the wider targets of the EU (BDR Thermea Group, 2024).

There are companies that perform actions where users have a circular solution, in particular Heat as a Service (HaaS). The Danish Energy Agency Heat as a Service initiative (HaaS) is designed to encourage take-up of heat pumps for use in single-family homes, especially where there is no district heating (Danish Energy Agency, 2021). With these structures, energy service companies install, own and maintain heat pumps and homeowners pay for the heat delivered via a subscription fee, while shifting the large upfront fee and technical management to others. This scheme also governs the end of life disposal of the heat pumps as that is for the companies partaking in this scheme to manage (Danish Energy Agency, 2021). A HaaS pilot project in 2016 showed the opportunity to work in HaaS, then launched a more permanent scheme in 2020 to subsidize energy service companies to replace oil and gas-fired boilers with air-to-water heat pumps in non-district heating areas. The program aims to help achieve the Danish government's aspirations to be climate-neutral by 2050 by making the upgrade to renewable heating hydrogen possible (Danish Energy Agency, 2021).

Bornholms Affaldsbehandling (BOFA)
An important partner in this project is BOFA (Bornholms Affaldsbehandling), a company of Bornholm Regional Municipality that is concerned with waste management for the municipality on the island. BOFA's primary responsibilities include completing the waste collection, treatment, and recycling of waste in an environmentally sustainable manner and through education and training.

Moreover, BOFA plays a large part in the shared desire to develop Bornholm into a zero-waste island by 2032, eliminating the use of landfills completely and integrating waste management into circular economy systems. Another part of the development for a value-based circular economy on Bornholm will be done together with the community in the form of education and programs to create sustainable lifestyles (BOFA, 2024).

Along with solid waste management and recycling and sorting services offered by BOFA, there is a group within the company who are running innovative pilot projects and developing uses for the circular economy.

Bornholm's Energi & Forsyning (BEOF)
Bornholms Energi & Forsyning (BEOF) is a municipally owned multi-utility company that plays a central role in Bornholm's transition to carbon neutrality and sustainability. The company provides approximately 40,000 island residents with electricity, district heating, water, and wastewater services. BEOF is a key stakeholder in the promotion of circular and green solutions on the island.

In addition, BEOF is actively involved in several innovative projects that support sustainability and circularity, in which some of the projects are managed by external partners. Some of the projects that BEOF is participating in order to drive sustainability, are Sustainable Bottom Line Bornholm (Bæredygtig Bundlinje) and Baltic Energy Island Initiative.

BEOF is a pivotal stakeholder in Bornholm's journey toward sustainability and circularity. Through its renewable energy initiatives, efficient resource use, and participation in forward-looking projects, BEOF exemplifies how local utility companies can enable meaningful and scalable climate action.

Installers - Flemming Svendsen VVS
Similar to the role of an advisor, installers are already employed as technical experts in their responsibility of advising consumers on what multiple heat pump types are available. In Bornholm, the installers perform all of the services for cleaning, heating and ventilation, and are certified by the Danish Safety Technology Authority to perform heat pump installations (Danish Safety Technology Authority, 2024).

On top of that, installers are trained and very knowledgeable with the repair and service of heat pumps as a component of their occupational duties. They are perhaps somewhat technically capable with the product and in fact are responsible for providing service.

Therefore, building on this technical expertise, both newly educating, upskilling, and reskilling via Short Advanced Courses in Circular Economy approaches like the 9R model, seems relevant and necessary for both installers and the future circular economy of the household energy system.

As part of this project, several installers on Bornholm were contacted, but only one company chose to participate in the research. Flemming Svendsen VVS, a plumbing firm specializing in the supply and installation of heat pumps on the island, was the sole participant (FL. SVENDSEN VVS, 2024).

Retailers - A/O Johansen
There are also other potential benefits in the supply chain, heat pump retailers. They sit lower down the supply chain between manufacturers and either consumers or installers. Retailers have participated in various programs to encourage efficiencies and more sustainable changes, sometimes

with local consultancies or with the government through units to support subsidy based programs of new heat pump installations.

A/O Johansen is an authorized heat pump retailer whose customer base consists exclusively of installers or certified plumbers and electricians. Currently, the company is not involved in any circularity initiative related to heat pumps and operates across all of Denmark.

End-users
Heat pump consumers also play a key role as stakeholders in Bornholm's shift toward a circular economy. As end users, their choices, behaviors, and involvement greatly affect the success of circular initiatives like product return systems, reuse programs, and the adoption of technologies such as heat pumps. On Bornholm, consumers are not just passive users but active contributors within a real-world testing ground for sustainable innovation. Research on circular economy behavior shows that user participation is driven by clear communication, meaningful incentives, and the perceived environmental and financial benefits of engaging in circular practices (Kirchherr, J., Reike D. and Hekkert, M., 2017).

Recycling Companies
Recycling companies play a vital role in the infrastructure and implementation of the circular economy by enabling the recovery, processing, and reintegration of materials into production cycles. These actors operate at the intersection of waste management and resource efficiency, transforming end-of-life products and industrial scrap into valuable secondary raw materials. In doing so, they contribute to reducing the demand for virgin materials, lowering greenhouse gas emissions, and minimizing landfill dependency. As key enablers of material circularity, recycling companies influence the effectiveness of take-back systems, extended producer responsibility (EPR) schemes, and industrial symbiosis strategies. Their operations support national and regional sustainability goals by closing material loops and supporting the design of waste management systems that align with the principles of reduce, reuse, and recycle. Recycling companies are considered as a different stakeholder than BOFA in this project, due to their difference in ownership, role and scope. Recycling companies in this case include private-own companies that operate nationally or internationally and provide commercial recycling services, regularly operating as for-profit business. In comparison to BOFA, which is publicly owned waste management company that promotes the zero waste goal for Bornholm, while focusing on environmental goals and citizen engagement.

Danish Technological Institute
The Danish Technological Institute (DTI) is one of the key contributors to circular economy efforts in Denmark with a focus on sustainable heating technologies. In the arena of developing sustainable heating technologies, internationally, through the annex (Annex 65: Heat Pumps in a Circular Economy), the DTI is exploring ways to improve the material efficiency, recyclability, and design of domestic heat pumps. Their project aims are to define 'circularity' concepts, scope existing end-of-life practices, and explore industry guidelines to help develop circular design in heating appliances. It is important that DTI looks at heat pumps and environmental outcomes as it relates to energy and circular economy aims.

Within the Bornholm context DTI is supporting the aspiration that Bornholm will be a demonstrator for circular and the decarbonisation of living. The embedding of smart and efficient heat pump systems is a key part of it, aligned to the larger agenda of energy transition and waste reduction. DTI's contribution is supportive to local initiatives such as EcoGrid 2.0, where households on Bornholm have been living laboratories for demand-side flexibility, which has enabled even intelligent control of heating systems, to balance the use of electricity from renewable electricity. (State of Green 2022). The technical expertise and applied research of DTI sits at the intersection of circular business models, product take-back strategies and design-for-disassembly frameworks. This positions the Institute as a key actor, for producing scalable, circular heating systems both on and off the island.

Policy makers and Regulators
Policymakers are among the key stakeholders influencing the heat pump market. Since heat pumps are categorized as electrical waste, their disposal must comply with the EU WEEE directive. In addition to that, the Danish Producer Responsibility System (Dansk Producentansvar, DPA) manages extended producer responsibility (EPR) for certain types of electrical and electronic waste. However, the current enforcement of the WEEE directive limits the ability to implement pilot projects that incorporate circular economy principles and foster collaboration among stakeholders.

Concluding Chapter 2, the current state of heat pumps reveals a conflicting narrative. While they play a crucial role in enhancing energy efficiency and cutting carbon emissions, their integration into circular economy practices remains limited. Throughout their life cycle, from production to disposal, the heat pump industry largely follows a linear model, which hinders broader sustainability objectives. Although frameworks such as the WEEE Directive and the Danish Action Plan for Circular Economy provide some guidance, they fall short of comprehensively addressing the full environmental impact of heat pumps. An exemption of this is the HaaS program from the Danish Energy Agency that is ongoing and can be highlighted as a stimulating pioneer for the heat pump sector.

Bornholm's initiatives in circular economy and sustainable waste management present a strong example, yet they also expose the lack of targeted strategies for handling heat pumps within the island's zero-waste ambitions.

The insights outlined in this chapter underscore the sector's inconsistencies, setting the stage for a deeper analysis of the core issue. The next chapter will define the central problem and introduce the research questions, underlining the urgent need for circular solutions and stakeholder cooperation to close the existing gaps.

Problem definition

Electronic and electrical waste are increasing at a fast rate, and the need of society for more advanced systems of managing EEE waste is growing at the same pace. Heat pumps, as part of the EEE, are also expected to increase production, due to the energy efficient technology that is provided and also because of the use of electricity compared to a gas boiler. From the goals established from EU, in the Green Deal and REPowerEU, heat pumps are one of the key technologies that can transition the system of heating and cooling to sustainability, in the occasion when renewable energy is the supplying energy for the heat pumps to be sustainable. Although there is a strong focus on accelerating the production and market implementation of heat pumps for both residential and commercial heating, a significant gap remains regarding the end-of-life management of these systems. This project, within the context of EU-NESSIE Interreg-project, focuses on the advanced circular island of Bornholm and explores the implementation of circular economy strategies on it, while exploring the stakeholder engagement on the sector of heat pumps and what are the adaptive solutions that can transition the present circumstances of the heat pump business sector in a more circular business model that faces the challenges of managing end-of-life heat pumps. The research question that was inspired by the problem analysis and the 2 leads to the following formed question as the main research question and the above sub-questions.

Research Question

How can the co-design of a take-back system in Bornholm from stakeholders in the heat pump sector be an innovative strategy for the transition to a circular economy by implementing the 9R circular strategies?

To answer the problem definition, there are three sub-questions that are essential to focus on:

1. How can the combination of circular economy strategies and eco-innovation create a system of preserving value for heat pumps among different stakeholders in the heat pump sector?

2. What role do key stakeholders in the heat pump sector in Bornholm and in Denmark play in enabling the 9R circular strategies in a take-back system for heat pumps and how can an advanced take-back system be set as a solution?

3. What is the contribution of the potential final circular design solution for heat pumps in Bornholm and how can it be set as an example for others?

Sub-question 1 is addressed in Chapter 4, which examines the circular economy framework, among the circular economy principles and strategies, and outlines the theoretical framework of the project, including references to previous examples of take-back systems found in the literature and a closer look on the innovation theory for business models that focus on circularity.

Sub-question 2 is answered in Chapter 6, where both components of the question are explored in depth.

Sub-question 3 is also discussed within Chapter 6. Finally, the main research question of the project is answered comprehensively in Chapter 8, where the overall conclusions of the project are presented.

Theories and concepts

This chapter presents the theoretical framework that underpins the project. The theories and concepts outlined here provide the foundational knowledge necessary to address the first research question: *How can the combination of circular economy strategies and eco-innovation create a system of preserving value for heat pumps among different stakeholders in the heat pump sector?* Serving as a bridge between the problem analysis and problem definition, this chapter lays the groundwork for the subsequent analysis and results of the project.

4.1 Circular economy framework

Given the increasing evidence that finite natural resources are being rapidly depleted, that current consumption exceeds the planet's capacity to regenerate, and that environmental conditions are unlikely to improve without significant change, there is an urgent need to reimagine how we live, produce, and consume (Murray, Skene, & Haynes, 2017). In response to these realities, the circular economy offers a framework for guiding the transition to a sustainable system of living, producing, and consuming, aiming to reduce waste and increase resource efficiency (Murray, Skene, & Haynes, 2017).

4.1.1 The definition of circular economy

The circular economy (CE) enhances the value of materials by preventing waste generation and maintaining materials within a closed-loop system (Ellen MacArthur Foundation, 2024). Achieving this ongoing circulation through maintenance, reuse, recycling and composting, it is reducing the need for virgin materials and decrease the energy for new product manufacturing. Therefore, the circular economy also addresses climate change because it works to reduce resource use, waste, pollution and emissions, and separates economic growth from finite resources (Ellen MacArthur Foundation, 2024).

Circular economy is also referred to as a production and consumption model that seeks to emulate nature's capacity to create balanced, cyclical, and closed-loop systems (Wang, H., et al., 2022). Additionally, it can be defined by different stakeholders with a different meaning, responsive to different roles and responsibilities (Wang, H., et al., 2022).

In relation to products, circularity can be understood as a characteristic of the system that relies on three key elements: 1. designing products to support the extension and closure of material loops, aligning with principles that slow resource consumption and promote reuse, 2. implementing business models that support the prolonged use of products and the recovery of valuable materials, and 3. fostering supply chain collaboration and stakeholder engagement to keep resources in circulation and enhance collective value creation (Dokter, G. et al., 2023).

Although the circular economy is increasingly embraced as a desirable systemic approach by companies, various governments, and the EU, many authors have highlighted challenges such as the lack of standardized definitions and strategies, as well as the need for stronger collaboration among stakeholders (Korhonen, J., Honkasalo, A. Seppälä, J., 2018). Multiple complementary theories underpin the circular economy concept, each playing a vital role in enabling its effective implementation.

4.1.2 Complementary theories for Circular Economy Implementation

The circular economy is defined not as a standalone theory, but as a multidisciplinary conceptual framework that aims to redefine traditional economic models by promoting closed-loop systems in which resources are continuously reused, repaired, or regenerated. Rather than offering a predictive or explanatory model like a formal theory, the circular economy provides a normative vision for transitioning away from the linear "take-make-dispose"model towards more sustainable modes of production and consumption. Theorems that can be characterized as complementary for the implementation of circular economy are institutional theory, stakeholder theory, and systems innovation theory.

Institutional theory
Institutional theory emphasizes the importance of societal norms in shaping organizational behavior, except for technical and economic considerations (DiMaggio, P. J., & Powell, W. W., 1983). Organizations tend to align their practices with the expectations of regulatory agencies, consumers, and professional bodies in order to maintain legitimacy, even when such expectations conflict with what might be considered the most technically efficient or optimal course of action. In the context of sustainability and the circular economy, institutional pressures can enable or hinder innovation (Wijen, F., & Ansari, S., 1983).

Institutional factors such as laws, informal social norms, and industry practices heavily influence the degree to which circular strategies such as 9R and take-back systems can be adopted. Often, regulations are designed around linear economic models and do not yet fully accommodate circular practices.

Stakeholder Theory
The stakeholder theory describes that organizations must create value for all stakeholders to be sustainable in the long run (Freeman, R.E., 1984). Stakeholder theory emphasizes the relationship between a business and the network of stakeholders that affects or is affected by it. In the context of the circular economy, effective stakeholder collaboration is relevant for the transition to the circular economy due to the possibilities of collaboration, co-design, and sharing value creation across supply chains and communities (Murray, Skene, & Haynes, 2017).

The success of the various circular business models depends on the successful collaboration and participation of multiple stakeholders, while the communication between them is based on trust, participation, and mutual benefits (Murray, Skene, & Haynes, 2017). The foundation of stakeholder theory in the circular economy concept helps in the implementation of circular strategies to be more inclusive and socially responsive, positioning sustainability as a co-created process rather than a top-down corporate strategy, since it relies on the balance between economic, environmental, and social priorities (Donaldson, T., & Preston, L. E., 1995).

Systems innovation theory
Systems innovation theory defines that sustainable transitions require coordinated changes across multiple interconnected systems. Technologies, infrastructures, user practices, cultural meanings, regulatory frameworks, and market structures evolve together in "socio-technical regimes". Radical innovations, such as circular take-back systems, often face resistance because they challenge dominant regimes.

Successful transition requires niches, where innovations can develop without immediate competition, until broader systemic conditions become favorable. Policies that support niche development, experimentation, and learning processes are key.

4.1.3 Circular Oriented Innovation

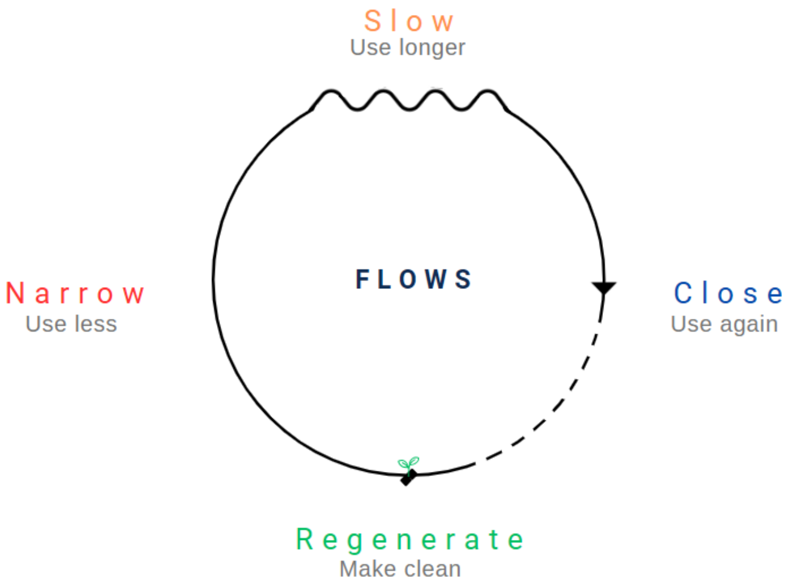
The concept of Circular Oriented Innovation (COI) is valuable as it brings together elements of product design, innovative business models, and value network structures, offering a comprehensive lens to explore how circular economy strategies can be effectively implemented (Dokter, G. et al., 2023). Furthermore, the real-world lifespan of a product is shaped by various socio-economic factors, such as the user behavior. It is essential that different systems are created that can be implemented in small-scale projects, within the framework of circular economy, in order to evaluate the feasibility of a circular product design, when combined with a circular business model and a particular supply chain setup (Dokter, G. et al., 2023).

4.1.4 Narrow - Slow - Close - Regenerate

The literature recognizes four circular economy strategies that can be used within systems: narrowing, slowing, closing, and regenerating resource loops.

First, the narrowing principle is focused on minimizing the amount of products, materials, and energy that are used throughout the product life cycle, including design, manufacture, consumer usage, and ultimate recovery (Konietzko, J., Bocken, N., Hultink, E.J., 2020).

The slow principle is concerned with extending the functional life of the product so it can be used longer without undermining its value or utility. Extending the functionality of a product is often aligned with designing it to last or providing the product as a service rather than a one-off purchase.



Figur 4.1. The narrow - slow - close - regenerate cycle (Own photo)

The close principle deals with closing the material loop of a product once it has complete its life cycle, through recycling products and returning them in original or reprocessed format, without significant loss of quality, which allows to reincorporating them back into production cycles.

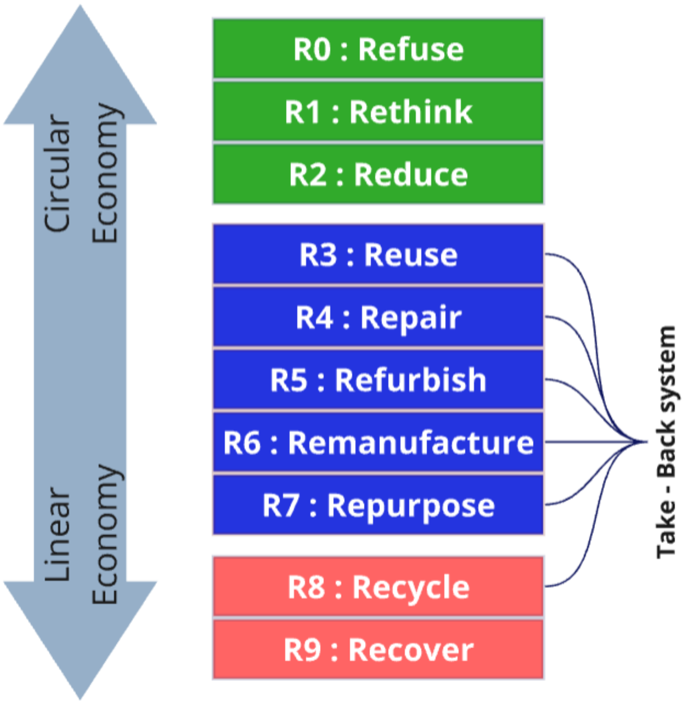
Lastly, the regenerate principle is concerned with the restoration and renewal of the limited and finite resources in order to maintain the health of the surrounding environment. The regenerate principle is both preventative and restorative. This means avoiding toxics and decreasing your reliance on finite resources and working on products made from a biodegradable or organic matter that can return to the ecosystem safely, while renewing the resources rather than consuming those resources (Konietzko, J., Bocken, N., Hultink, E.J., 2020).

The figure 4.1 illustrates the cycle of the Narrow, Slow, Close, and Regenerate principles, showing how they are interconnected through the flow of materials and products. Alongside these principles, the literature also presents the R strategies, which complement and expand upon the circular economy framework.

4.1.5 The 9R's

The strategies to utilize in moving from a linear economy to a circular one vary greatly. Because the dimension of circularity is vast, and no strategies have been homogenized across scientific, technical, and legislated dimensions, many ways have been developed to lead to this type of transition (Zorpas A.A., 2024).

As a result, there exists a multitude of R strategies within the circular economy framework. A recent article highlights that there are as many as 55 different R strategies related to circular economy and waste management, extending far beyond the traditional reduce, reuse, and recycle principles. However, this project focuses on the well-established 9R strategy, which is illustrated in Figure 4.2.



Figur 4.2. The array of the 9R's (Own figure)

There is a clear congruity within the lists of circularity strategies, which typically provide a hierarchical definition of R strategies ranging from high to low circularity measured against product life cycle times, with the least circularity strategies being essentially a linear take on product production to disposal by getting it back to landfill as fast as possible. The more circular performance indicators are organized around reducing material demand across the product life cycle, since they require fewer resources to provide the same function (Potting, J., et al., 2017).

For example, R0: Refuse has the reductive quality of making a product redundant. The product can be redundant with either the function no longer needed or the same function being provided by a radically distinct product. R1: Rethink enhances the product with the idea of using products more intensely to reduce consumption with the aim of maximizing capital utility of each unit. R2: Reduce the consumption of natural resources and/or materials by using a more efficient product (Kirchherr, J., Reike D. and Hekkert, M., 2017).

With the goal of increasing the production or its components useful life, the R3 to R7 strategies apply with lower numbers being more circular.

R3 - Reuse is the continued use by a consumer of a product at the time of disposal and the continuation of its original purpose.

R4 - Repair is to maintain a defective product in good working order to continue using the originally intended purpose.

R5 - Refurbishment is to upgrade a worn product to return the item to its original state or improve performance.

R6 - Remanufacture is the act of disassembling product and restoring similar function by replacing worn parts with new ones.

R7 - Repurpose is defined as creating a new product with a different purpose using an old product or components of an old product.

The last set of circularity strategies identified in the array are the low circularity strategies R8: Recycle and R9: Recover. These low circularity strategies are somewhat representative of the linear economy as circularity seeks to keep resources usable for as long as possible at their highest functions. R8: Recycle redirects discarded products to process them into raw materials to manufacture new products or R9: Recover takes discarded un-recyclable waste products and captures energy, traditionally by incineration (Kirchherr, J., Reike D. and Hekkert, M., 2017).

One of the most commonly adopted circular strategies, by a variety of actors in the supply chain, is recycling, a strategy that is highly energy-intensive for the acquisition of recycled raw materials and often results in loss of product value (Wandji, C., et al., 2025). However, circular strategies of reusing, repurposing, remanufacturing, and refurbishing are more challenging to implement in the economy due to significant variability of products and the end of their life cycle (Wandji, C., et al., 2025). This creates a great gap for manufacturers and companies that aspire to transition to the circular economy, to decide which circular strategy to follow to be the most profitable for both the environment and their economic prosperity (Wandji, C., et al., 2025).

4.1.6 Comparison between the circular economy frameworks

Aside from the 9R framework, several systems describing circularity exist. These systems differ in terms of focus, application, and limitations. The 9R strategies are particularly well suited to this project when compared to others for the following reasons.

For example, the Butterfly Diagram provides a visual representation of the circular economy, distinguishing biological and technical cycles, illustrating how materials and substances can be safely returned to the environment within a biological cycle, and that within a technical cycle, the focus is on keeping the value of the product intact through means of reuse, repair, refurbishment, and recycling (Ellen Macarthur Foundation, 2021). While the Butterfly Diagram culture provides a solid overview at a high level, it does not address what the proposed, practical strategies would be. The 9R framework, by comparison, is more granular, hierarchical in action, and its principles prioritize keeping the product's value for as long as it is reasonable to do so, and thus is also more suited to designing a specific take back.

Following that, the Performance Economy framework is focused on extending product lifetimes through service-based business models like leasing, renting, or sharing, rather than ownership. It promotes durability, service, and repair and only considers economic value while emphasizing keeping products and materials in circulation for as long as possible (Ellen Macarthur Foundation, 2014). Although it effectively promotes circularity through functional services, the framework usually emphasizes economic issues over environmental impacts and specific material cycles to a lesser degree.

In circular economy theory, the Cradle-to-Cradle framework wants products and systems to be designed so that materials play the role of nutrients that flow continuously in biological or technical cycles. The framework advocates for eco-effective design and waste-free processes; the goal is for materials to be safe for biodegradation or perpetually reused in production again (Hoang, K.M. and Böckel, A., 2024). That said, with broad principles and complexity, certification of Cradle-to-Cradle is often difficult to figure out in a practical way and can be a little idealistic.

Another interesting framework is the Circular Economy Biomimicry framework. The circular economy biomimicry framework is based on natural ecosystems and regenerative design principles that eradicate waste and maintain materials in continual closed loop cycles aligned with natural processes. The circular economy biomimicry framework promote design methods based on nature's strategies, however due to its breadth and conceptual content it often lacks the practical detail necessary for industry use (Lebdioui A., 2022).

Unlike these broader frameworks, due to the more nuanced 9R structure, the 9R framework is ideally suited for use in take-back systems. The 9R framework provides a clear process for managing heat pump products through the entire products life, from design and use to end-of-life recovery that optimizes resource efficiency and closely aligns with circular economy principles. The 9R framework also guides stakeholders in the systematic design, use, and recovery of products while working towards some specific environmental objective (Blomsma F. & Brennan G. , 2017).

4.2 Take-back systems

In a circular economy (CE), a take-back system is an important mechanism where organizations, companies, or associations take back products, components, or materials from end-users at the end of their initial use. Take-back systems are used to retrieve and reintegrate the remnants of products back into production so that it relies less on virgin raw materials. In the CE paradigm, the reclamation of such products systems occurs in various R strategies such as recycling, remanufacturing, refurbishment, repair, and reuse, while following a closed-loop model instead of the linear economy of "take-make-use-dispose"(Uhrenholt J., et al., 2022). In particular, value creation within a circular economy system is increasingly associated with strategies such as the use of take-back schemes, which emphasize reuse and reuse potential of products after their initial use. Referring to value creation in the context of CE, it emphasizes that value is created in terms of keeping resources within the system. Value is added when a product or material can be salvaged and recovered for reuse (Jørgensen R. et al., 2025).

The implementation of take-back schemes across many product sectors allows us to highlight multiple advantages, such as in the case of cotton recycling. It comprises benefits to the environment through reduction of landfill waste, reduction in greenhouse gas emissions, reduction in energy use, and reduction in water use. Socially, take-back schemes raise the awareness of consumer stewardship towards sustainable consumption and increases participation among individuals when using take-back schemes for stewardship. Economically, take-back schemes provide both consumers and companies with subsidy savings, cost savings on products, and create circular market value opportunities (Roy, S., Chu, Y.Y.J., Chopra, S.S., 2023).

Moreover, this study demonstrates the substantial possibilities of take-back systems still in the textile area, particularly in mitigating the considerable environmental impacts of fashion. The main benefit of establishing a take-back system in this area is the reduction of virgin raw materials needed. There is also a positive social dimension to the study findings in that consumers are typically more willing adopters of products made of recycled materials.

Although take-back systems could produce significant advantages for the textile fashion sector, there are limits to advances in take-back systems. The management of post-consumer waste is a large challenge due to poor sorting and accounting of returned products. Inadequate organizational knowledge, regulatory environments, gaps in expertise, and understanding of best practices continue to be poorly understood and to vary across organizational contexts. This analysis shows it is important to develop take back systems through legitimate and thorough testing, and to have better buy in and integration of take-back systems among more companies and on a greater scale (Roy, S., Chu, Y.Y.J., Chopra, S.S., 2023).

Further studies on the recyclability of end-of-life electronic products primarily address technical challenges and quantity-related issues associated with implementing take-back systems. Typically, take-back systems target specific fractions of Waste Electrical and Electronic Equipment (WEEE). Notably, a Life Cycle Assessment (LCA) study has demonstrated the clear environmental benefits of a Swiss WEEE take-back system (Hischier, R., Wäger,P. and Gauglhofer,J., 2005).

Although there are environmental advantages, the specific study highlights that recycling WEEE also causes environmental impacts due to the production of secondary raw materials (Hischier, R., Wäger,P. and Gauglhofer,J., 2005). The balance between minimizing environmental damage is further explored in the study by Hischier et al., which examines the combination of take-back systems and eco-innovation, particularly within firms and other organizations (Hischier, R., Wäger,P. and Gauglhofer,J., 2005).

Jørgensen et al. (Jørgensen R. et al., 2025) come to the conclusion that alignment of purpose between actors to treat products according to their requirements can result in value creation in a take-back system. In combination with the transition to the circular economy, in order to capture the value that is created from discarded products, it is important for stakeholders to consider these products as a form of resource and not as waste. Based on that, the transformation of linear production into closed-loop production demands collaboration between actors, who are both responsible for designing a product and for consuming and managing the product (Jørgensen R. et al., 2025).

Another example of a take-back system implementation is Matas Group's Return System for packaging of all of their products. This return scheme was presented in the LOOP forum, expanding on the missteps about the implementation and providing advice about their knowledge in return systems (Matas, 2025). The focus was set in five points of advice from many years of implementation of the return system. The first focus point was on the involvement of the value chain from the beginning of the project and the importance of information about the waste that the system has to handle. The second focus point was on describing the design of the system and how it should consider the feedback from various stakeholders involved in the system. The third focus point was on the engagement of the right stakeholders in order to set the right plan of the system's feasibility and operation. Last but not least, the fourth focus point was referring to the data-driven decision making from the company, which they evaluate the scheme and calculate the effects of operational systems like the return system. The Matas Return System was set to be an example of a failed return system for recycling the packaging of millions of products, although it provides valuable information for possible future return systems on what to avoid and where to focus in order to be feasible. [1]

Another case study that explores the circular practices that are applied in Denmark and specifically on the island of Bornholm, deals with the construction and demolition waste and investigates the potentials and barriers of a return system (Christensen, T.B., et al. , 2022). Analyzing the conditions on the island of Bornholm about the construction and demolition waste, the study reveals some positive feedback for the implementation of circular strategies in the island in relation to creating a circular value chain in the construction sector of the island (Christensen, T.B., et al. , 2022). The study focused on the recirculation of specific construction materials on the island, which appear to have a more viable business value compared to other construction and demolition materials (Christensen, T.B., et al. , 2022). The specific study provides theoretical information, based on empirical testing, valuable for this project, because of the same case islands, and the focus on implementing circular practices in sectors that need new business plans and innovative initiatives.

In addition, several studies highlight the benefits of implementing the 9R strategies across product, material, or component supply chains, whether through industrial ecology and cleaner production methods or during the customer disposal phase. This approach transforms the supply chain into a closed-loop system that emphasizes reuse, repair, and refurbishment, thereby keeping materials in circulation for an extended period (Wang, H., et al., 2022).

There is strong cooperation between circular economy (CE) systems, including take-back systems, and eco-innovation within the industrial sector, which has been proven to bring benefits both environmentally and in terms of customer satisfaction. Furthermore, sustained adoption of take-back initiatives combined with environmental innovation performance can lead to the development and implementation of more environmentally conscious policies.

4.3 Innovation Theory

Innovation is a complex and multidimensional process of creating, executing, and socially accepting an idea, product, service, or process (Kochetkov, D., 2023). Innovation encompasses technological and economic progress and promotes deep changes to social and behavioral habits. The process of innovation can be characterized by many participants within a multidisciplinary environment that draws on knowledge from fields such as economics, management, sociology and psychology. Social change and wider objectives, such as sustainable development, also characterize the innovation process (Kochetkov, D., 2023).

Innovation in existing production and consumption systems is a key tool for the transformation towards a circular economy. Many scholars focus on ecological innovation as a new solution to the adverse environmental challenges that arise from existing production and consumption systems (Pichlak M. Szromek A., 2022). The term of ecological innovation (eco-innovation) is defined by Kemp and Pearson as "the production, assimilation or exploitation of a product, production

[1] This information were collected by the participation of the author in the LOOP Forum 2025, where Matas Group presented the information of their take-back system.

process, service or management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction in environmental risk, pollution, and other negative impacts of resources use (including energy use) compared to relevant alternatives"(Kemp R. Pearson P., 2007). This definition provides a general framework that focuses on the implementation of eco-innovations with regard to environmental impacts, while it is proven to have economic benefits, as well as social and environmental benefits (Pichlak M. Szromek A., 2022).

The connection between eco-innovation and circular economy is considered in three different categories, product eco-innovation, process innovation, and organizational innovation (Pichlak M. Szromek A., 2022). For the product eco-innovation, in order to transition from a linear to a circular economy, it is necessary the circular practices to be considered in the full life cycle of the product, from the design phase to the end-of-life. A very impactful phase of the life cycle of a product is the design phase, because it determines the environmental impacts that a certain product has in the recycling or recovery phase (Pichlak M. Szromek A., 2022). Therefore, due to the alignment with circular economy practices, the development of products, considering the environmental impacts that they will have in their full life cycle and including them as aspects in the development of the product is the framework of Eco-design. In the manufacturing context, eco-design is another aspect of the product design process, among functionality, durability, quality, cost, and safety (Pichlak M. Szromek A., 2022).

However, limitations exist in implementing eco-innovation and developing products with the eco-design framework, such as the additional costs and time investments required to adopt eco-innovative solutions, as well as risks associated with altering core organizational principles. These limitations are further compounded by gaps in empirical evidence regarding the efficacy of combining eco-innovation and CE in practice (Pichlak M. Szromek A., 2022).

A take-back system represents a compelling example of eco-innovation in action, particularly when integrated within a circular economy framework. Such systems facilitate the collection, refurbishment, reuse, or recycling of products at the end of their life cycle, effectively closing the resource loop. By adopting take-back initiatives, organizations can reduce waste, minimize environmental impacts, and promote sustainable production and consumption. Moreover, take-back systems can drive innovation in business models, such as shifting from product ownership to service-oriented models such as leasing or product-as-a-service, further enhancing resource efficiency.

Additionally, take-back systems facilitate collaboration among various stakeholders, including manufacturers, consumers, and waste management organizations, creating opportunities for industrial symbiosis (Pichlak M. Szromek A., 2022). A take-back program for heat pumps could incorporate eco-innovation by enabling the reuse of components, the recycling of materials, and the reduction of energy consumption during production. This approach not only mitigates environmental risks, but also strengthens the local economy by creating jobs in repair, recycling, and logistics.

The implementation of eco-innovation into take-back systems can provide an organization scalable and practical solutions for applying CE principles. These systems show that the combination of eco-innovation with circular economy strategies can have significant impacts on environmental, economic, and social dimensions, despite the challenges of cost and organizational change (Wang, H., et al., 2022).

4.4 Reflection on the theoretical framework

The theoretical framework selected for this project combines circular economy strategies, eco-innovation, and take-back systems, offering a comprehensive foundation to explore how value can be preserved in the heat pump sector. This interdisciplinary approach provides the opportunity to address the complexities of implementing circular practices across various stakeholders. Moreover, by comparing multiple circular economy frameworks, the selection of the 9R model is justified for its practical orientation and applicability to designing schemes of return products. Similarly, the incorporation of eco-innovation and eco-design frameworks adds valuable insight into product development and system transitions.

However, certain enhancements on the theoretical foundation must be taken into account. Though the chapter emphasizes an integrated approach, its coverage would benefit from more explicit inclusion of behavioral and economic theories, particularly those that deal with consumer participation in take-back systems or economic incentives for manufacturers. Additionally, though stakeholder theory is cited, more distinction between types of stakeholders (e.g., policy-makers vs. SMEs vs. end-users) would strengthen the discussion of collaboration issues. One aspect to be enhanced is the inclusion of more empirical frameworks or models that address the implementation issues of real circular transitions. Finally, while the theory chapter provides a good conceptual basis, future iterations of this research can attempt to operationalize these theories more directly into measurable variables or indicators to guide practical implementation.

In summary of Chapter 4, the core theories and concepts that inform the project's transition from a linear to a circular economy have been described. The project has explored pathways to transformation that utilize circular economy properties, particularly through the 9R framework, while incorporating designed take-back systems and eco-innovations. The project has established potential pathways to sustainability using strategies that emphasize narrowing, slowing, closing, and regenerating material loops to create value and hinder environmental impact on materials. This analysis has also begun to explore the implementation processes that accompany organizational changes within a wider system context. The project has highlighted the power of innovation, particularly eco-innovation when creating relationships between environmental and economic values. All of the concepts explored throughout the chapter provided not only some answers to the original research question but also a framework through which the analysis and findings of the project will be understood.

Methodology

This chapter outlines the methodology for the project, which uses a design-based research methodology that incorporates both desk research and qualitative interviews.

5.1 Design-Based Research

Design-based research is defined as "the systematic investigation of the design, development, and evaluation of educational interventions - such as programs, teaching strategies, materials, products, and systems - aimed at solving complex problems. It also seeks to enhance the understanding of the features of these interventions and the processes involved in their design and development" (Gerholz, K.H. and Wagner, A., 2022).

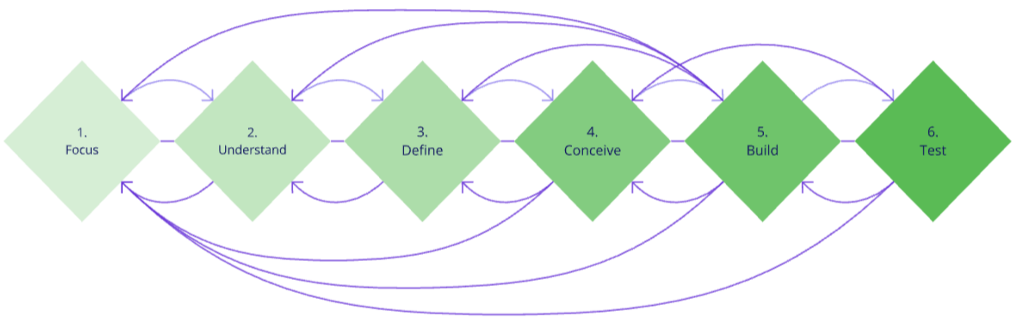


Image 5.1. Designed-Based Research method figure (Own figure)

The Design Based Research (DBR) methodology consists of six iterative phases, as illustrated in Figure 5.1, and each is explained in detail in this chapter. The process begins with the identification of a problem that exists in real life, followed by the evaluation of a practical solution that develops during the process (Easterday, M.W., Lewis, D.R., Gerber, E.M., 2014).

The first component of a design-based research methodology is to clearly define the problem in relation to the relevant sector. The researcher could be an embedded stakeholder or an independent entity that interacts closely with the stakeholders in the sector. This is a crucial aspect of design-based research that will clearly address the research focus, and delineate the factorial direction, paving the way for the study to arrive at a meaningful, and applicable solution (Easterday, M.W., Lewis, D.R., Gerber, E.M., 2014).

The second component sees the researcher building a nuanced understanding of the sectoral context. This stage, in design-based research, is intensive on data acquisition. It includes primary data, such as observations and interviews, and secondary data uses, such as surveys, case studies, and academic literature. This phase is essential in validating the gap in identified solutions in relation to the defined 'problem' and affirming the need for the 'intervention' proposed.The third stage requires us to segment the problem into smaller portions that can be dealt with explicit tasks and solutions. This segmentation allows us to make the problem easier to work with and identifies specific parts of a potential solution or intervention.

A key intended output of the third stage is a concise and answering research question, clearly indicating the intended direction of the research. This should be concise enough to be portable but enough to provide direction on the intended output at the initiation of a solution that will adequately address the original problem and research question.

Once the research direction is identified in third phase, there is an increase of the chance of proceeding with the intervention that is feasible, clear, and effective to address or at least mitigate the original problem identified in first phase.

The fourth step in the design based research draw to the initiation of the design of the intervention to ameliorate the problematic or troubling situation identified in the initial stages of the research. At this point in the design phase the designer is now creating an organized scenario of all the crucial elements of the solution including all the subordinate concepts and principles that are intertwined in the solution.

Although the solution can not be applied yet, and it is still theoretical, it describes precisely how this problem could be remedied, into an action of practice would occur in real life. The design is the foundation or precursor to the practice phase.

The last step in the design-based research methodology is to evaluate and test the model that has been created. In this step the proposed solution looks to be implemented and evaluated in a real implementation context in order to demonstrate how it does and does not solve the problem it is intended for. Evaluation likely included effectiveness, relevance, and fidelity to design.

Once again, this phase is vitally important for demonstrating the practicality and impact of the solution. Systematic observation and analysis will be employed to collect the information about the model's strengths and weaknesses. This information will serve two purposes. The findings will confirm that the model can achieve its intent and will detail any changes which need to be made to ensure that the final result can effectively meet the goals set out by a variety of stakeholders.

A defining characteristic of the DBR methodology is is that it allows for multiple cycles of iterations within a single phase or between several different phases. The ability to iterate means that there can be myriad representations of a solution that address an issue and it also allows - with appropriate record keeping - designers to continuously fine-tune the intended design, so that it is responsive to the problem context. The iterative nature of DBR can help pave the way for adjusted elements in the design stage and even implementation stages, to avoid excessive costing, including time, with modifications being iteratively planned not just allowed to occur in the situation. DBR provides avenues for opportunity for a valid, practical, and improving solution to be constructed (Easterday, M.W., Lewis, D.R., Gerber, E.M., 2014).

Design-Based Research (DBR) is differentiated from traditional research approaches in that it involves other stakeholders during the design and evaluation phases, achieving an outcome that is embedded in the realities and needs of the community. DBR engages multiple stakeholders in cumulative innovation strategies that address complex social problems through empirical justice and humanizing the active participation of all participants involved in social change, though DBR meets both theory building and solutions building. Simultaneously engaging in both theoretical and practical dimensions contributes to a multiplicity of understandings of the processes of implementation and socially constructive outcomes. The contemporary innovation for implementation is relevant to the reality and social impact of the research in practice.

DBR is used in this project to speculatively create and examine a take-back system for heat pumps, as a case to show how a take-back can potentially support the implementation of circular economy strategies.

The research problem presented in Chapter 3 is an identified and evidenced sustainable end-of-life solution for heat pumps. The project outcomes are the design of a take-back system for heat pumps in Bornholm aligned with circular economy strategies. The overall design development of the sustainable solution illustrates the iterative cycle of Design-Based Research (DBR), allowing the proposed solution to be contextualized, designed, and evaluated in conjunction with a variety of stakeholders in an interactive, close, and intimate position.

5.2 Qualitative interviews

Two distinct types of interviews were conducted in this research. The first type is termed semi-structured interviews, which have the purpose of collecting qualitative data to achieve in-depth insight from the participant perspective, with the opportunity for the interviewer to use a pre-existing flexible structure of open-ended questions, while still being able to carry on the interview and allow it to be changeable. This approach allows the interview to explore emergent themes and insights while remaining focused on the research objectives.

The second format is open-ended questionnaires intended to provide qualitative input in human meaning and understanding from a wider section of the participant population's experience, opinion, and reflective possessed experience from the participant, in their own thinking and words. Open-ended questions allow rich qualitative data to emerge and be reported; valid contextualized data that goes beyond providing research informed quantitative through standardized closed-ended surveys. Each question used open-ended questionnaires are explicitly prompted from research design thinking to elicit potential richness of responses to assure that rich contextualized data is reported from emergent unlimited meanings and if questioned from contextualized closed-ended thinking.

5.3 Desk research

This study began with desk research to develop an initial overview of the circular economy in relation to heat pumps, take-back systems and waste management. Desk research allowed us to review existing literature and data, and previous studies; it provided theory and related practice, offering suggestions about potential knowledge gaps that are important to explore. In conducting desk research, a review of secondary data, reports, case studies, press releases, and scholarly articles was also conducted, in addition to publicly available information. Desk research aided in producing a knowledge base, which was later supplemented with primary data collection, involving personal interview protocols. The combination of secondary and primary data provided a more comprehensive and balanced analysis. Nevertheless, desk research has limitations, in particular, the legitimacy of the sources. The primary gains were to treat documents with care, rely on well-established publications, and well-established theoretical frameworks to support our work so as not to include incomplete and incorrect conclusions.

Desk research also points out an important genesis for this study. The desk research in particular aimed to create a preliminary understanding of the circular economy within the heat pump arena, including the possibilities and challenges of implementing take-back systems, as well as a greater contextualized view of waste management. It undertook the task of reviewing a focused sample of existing literature, reports, case studies, and publicly available data in order to identify primary trends, map out a current reality, and surface knowledge gaps where original research could continue to add to the knowledge base.

This secondary data was obtained through a review of various sources (eg. EU policy documents, peer-reviewed articles, industry white papers, and press releases from suppliers and relevant organizations). These sources guided me in establishing what was currently in progress, where the regulatory world is headed, what environmental impacts were being noted, and what practical issues exist with circular strategies in the HVAC industry. The desk research in particular allowed me to identify some common factors, including key raw materials in heat pumps, the complex logistics involved in take-back systems, and eco-design used to improve longevity.

Additionally, this stage of the research informed the interview questions, and helped to shape the analysis of the interview data to make sure the primary data was focused on relevant items. The desk research and interviews provide a stronger comparison for validity, by comparing theoretical knowledge against people's lived experiences.

Nonetheless, there are limitations related to the use of desk research. The conclusions of any secondary research depend fundamentally on the integrity, objectivity, and recency of the data used. In this case, I ensured integrity by only using peer-reviewed or institutional sources, and limited my data to that which fits within existing theoretical paradigms for circular economy and sustainable design. While desk research was limited, it nevertheless represented an important first step in laying a foundation to build the primary research.

5.4 Reliability and Validity in the project

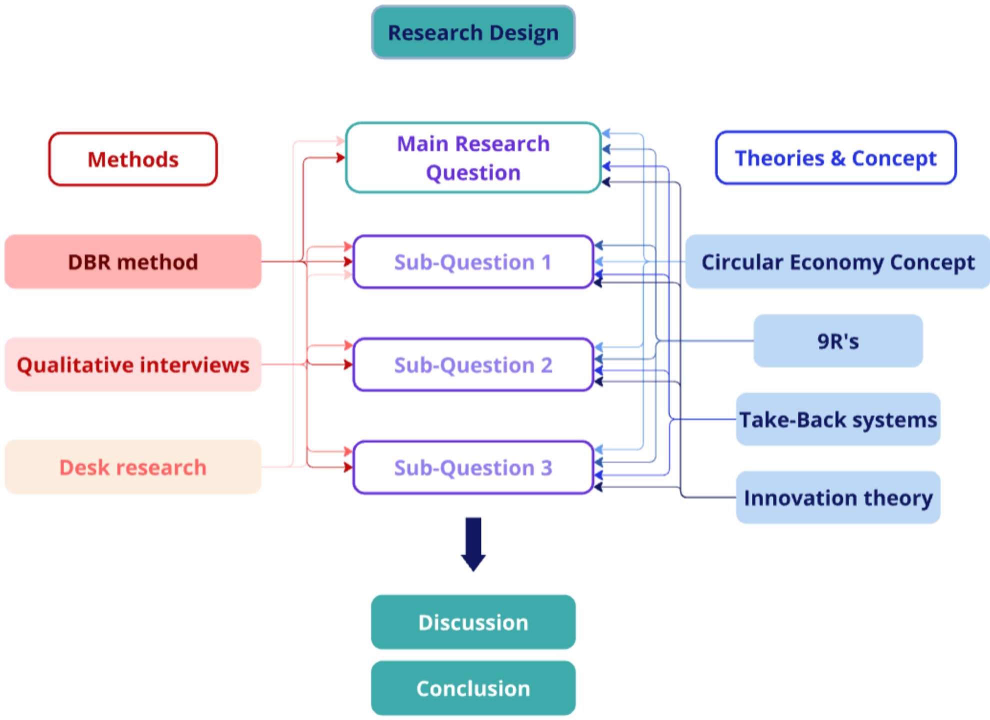
Reliability, validity, and limitations are significant aspects of this analysis. In quantitative research, the concern for reliability and validity is related to the accuracy of the measurement. In qualitative research, reliability and validity are concerned with knowing that the focus phenomena can be interpreted in several different ways, stressing the importance of depth and contextual understanding.

The limitations of the report are that the number of stakeholders who participated in interviews was relatively small, though the stakeholders represented a diversity of stakeholders represented in every group of the stakeholder map. If more time was available, there would have been opportunities to utilize the Design-Based Research (DBR) methodology further with several iterations in order to refine slowly the proposed solutions.

The semi-structured interview method permitted the use of standardized questions across all participants while allowing for the flexibility of participants to elaborate on topics that emerged from their particular context, improving the data quality and depth of information.

For this project, reliability is understood in relation to the consideration of all choices and omissions, which were made during the research process. The transcription of interviews also provided transparency and accountability to the study. The validity has been applied to the careful consideration of how to interpret the theories and methodological approaches, and constructing interview questions that were transparent and available to participants thus could enable important empirical data to be collected enhancing the validity of the report.

Generally, although one-fifth of the validity of the report is the quality and reliability of your own data collected, there is even more to understand as to what data is reliable and relevant along with the limitations of this study, which in turn facilitates, a more well-rounded understanding of your findings and further validates the report as well to strengthen credibility and validity.



Figur 5.2. Research design of the project (Own figure)

The research design is a presentation of where all the methods and the theories and the theories and input are providing the input and the mechanisms to research and respond to the main problem which is expressed in the Main Research Question and to identify and to answer of the Sub-Questions 1, 2 and 3 definition. The order of the research design has been led in the discussion and at the end is the chapter of conclusion of the project, at least. The visual presentation of the research design is in the figure 5.2.

In conclusion of Chapter 5, the approach in this project uses a combination of design-based research, qualitative interviews, and desk research to give attention to the complexities associated with taking back a heat pump through considering a circular economy framework. This project engages stakeholders, and practical application is emphasized, while the qualitative interviews and desk research were helpful in expanding an understanding of specific circumstances, challenges and opportunities. The consideration of reliability and validity adds to the rigor of the approach, and it provides another lens on credibility of findings, and credibility of the project's conclusions.

With the methodology displayed in the figure 5.2, the chapter that follows will analyze the data generated through research to explore the findings and answer the subquestions 2 and 3 of the problem definition stage, particularly when designing and researching a take back system under the specific and specific requirements of circular economy in Bornholm.

Analysis

Transitioning to circular economy (CE) necessitates the development of innovative systems designed to minimize waste, optimize resource efficiency, and extend the lifespan of products. Co-designing a system for heat pumps in Bornholm aims to integrate the 9R strategies in planning and managing the heat pumps in their end of life. BOFA and BEOF can serve as central stakeholders, leading coordination, implementation, and awareness efforts for this system. The following chapter answers both parts of the second questions of the problem definition *"What role do key stakeholders play in the heat pump sector in Bornholm and in Denmark in enabling the 9R circular strategies in a take-back system for heat pumps and how an advanced take-back system can be set as a solution?"*.

The analysis that follows interprets empirical findings through this integrated lens, using the 9R strategies as a taxonomy to evaluate the circular potential of current and proposed practices. It also applies the systems innovation and eco-innovation frameworks to examine feasibility and stakeholder perspective. Special attention is given to how companies, like BDR Thermea navigate these complexities, balancing economic viability with environmental ambition. By linking theory to practice, the analysis aims to uncover actionable insights into how circular take-back systems can support sustainable transformation in industrial settings.

6.1 Stakeholders on circularity in the sector of heat pumps

The stakeholder engagement can be very crucial in the implementation of circular practices. The section below explores how the different stakeholders recognize the feasibility, benefits, and challenges of integrating circular economy principles into the life cycle of heat pumps. They highlight local priorities, knowledge gaps from their perspective, and collaborative opportunities that see in the future that may influence a more circular transition in the energy infrastructure of Bornholm.

6.1.1 Local authorities (BOFA)

BOFA, as the primary waste management authority on the island of Bornholm and as a municipal entity, has implemented many different projects around the goal of a zero-waste society by 2032. They are set goals for a comprehensive sorting and recycling system of all waste streams on the island, while focusing on eliminating the need for incineration. BOFA's strategy contains the development of a waste and resource array that brings together businesses, educational institutions, and public organizations to promote innovation in waste treatment and resource utilization.

In relation to the heat pump sector, BOFA recognizes the importance of integrating circular principles into the life cycle of heating technologies. Although specific initiatives targeting heat pumps are not detailed in the available literature, BOFA's overarching commitment to resource efficiency and waste reduction suggests a proactive stance towards incorporating such technologies into their circular framework.

BOFA views the idea of implementing circular strategies as promising yet technically and structurally complex (Appendix 9.1). Drawing from their experience with the REuseLAB Bornholm project for refrigerators and freezers, BOFA acknowledges the environmental and systematic benefits of such systems in extending product life cycles, reducing waste, and fostering local repair and refurbishment economies. A take-back model involving refurbishment or reuse could serve as a valuable complement to current recycling efforts, aligning with broader life-cycle and resource efficiency objectives. BOFA recognizes that such strategies would lead to a more holistic understanding of circularity, not particular in material recovery, but one that prioritizes product longevity and upstream resource savings (Appendix 9.1). This perspective aligns with the view of eco-innovation theory, which stresses product and systems redesign to reduce environmental impact across the life cycle. BOFA's attempt to establish repair and reuse systems demonstrates higher-order circularity strategies, which align with the higher rungs of the 9R framework (R4–R6). However, the organizational and regulatory barriers they face also highlight what system innovation theory defines as 'regime-level lock-ins', institutional structures, and norms that resist radical change.

Although circularity benefits the sector of heat pumps, BOFA identifies multiple challenges in implementing circular strategies on the island (Appendix 9.1). Heat pumps are different electrical devices from other white goods in that they are fixed installations involving high voltage systems that can only be handled by certified professionals. Furthermore, their concern was expressed for the economic viability of a scheme focused on heat pumps, because of the limited number of heat pumps in the local system of Bornholm in comparison to the households that using district heating, which is 80% of the households on the island (INSULAE H2020 , n.d.). This fact raises concerns about economic viability, specifically whether sufficient units would be available to sustain repairing the service-based model. The regulatory limitations are also a challenge for BOFA, where Denmark's Extended Producer Responsibility (EPR) complicates BOFA's involvement in reuse efforts, as heat pumps are categorized as e-waste, EPR assume control over the product (Appendix 9.1).

6.1.2 BEOF

From BEOF's perspective, the feasibility of implementing circular strategies is characterized as optimistic with various challenges. The organization is already deeply involved in EU-funded sustainability projects, focusing primarily on optimizing energy systems through data collection (Appendix 9.7). These initiatives show that BEOF has the infrastructure and some technical expertise to support circular strategies. However, when it comes to integrating more advanced circular approaches, such as a take-back system for technologies like heat pumps, BEOF has not yet actively explored this area, acknowledging that such discussions have yet to occur internally (Appendix 9.7). There is technical and organizational knowledge, but there is no strategic plan or stakeholder coordination for particular actions to be taken. This lack of systemic coordination demonstrates a challenge addressed by systems innovation theory, which underscores the importance of multi-actor alignment and cross-sectoral governance in transition processes. The absence of structured dialogue across stakeholders limits the emergence of a shared innovation trajectory.

The potential benefits of the circular strategies that are being implemented are clear to BEOF, especially for future funding and improvement of sustainability credentials, while fostering innovation. João Møller emphasizes the value of collaboration with entities such as BOFA and sees opportunities to align with Bornholm's broader vision of zero waste and Energy Island (Appendix 9.7). The integration of strategies like Reuse, Repair and eco-design approaches could support Bornholm's role as a testbed for innovative and sustainable solutions and strengthen the island's position in European green initiatives. Circular strategies, particularly when linked to energy communities, could help reduce infrastructure strain, increase energy efficiency, and empower local involvement. All of these goals are aligned with the BEOF sustainability philosophy and ongoing Horizon and Interreg projects (Appendix 9.7).

Despite the potential of the system and the synergy between BOFA and BEOF, several challenges hinder the implementation at a full scale. BEOF faces structural and political barriers, such as limited local public funding, resistance from the conservative population of the island, and a lack of local installer expertise, according to João (Appendix 9.7). He also makes clear that due to the broader geopolitical context, whereby Bornholm's geography makes it at once asset and liability in times of regional insecurity. Furthermore, the lack of a single, multi-stakeholder vision of circular design, involving manufacturers, municipalities, and service providers, imposes boundaries on actionable momentum. To move forward, BEOF believes that affordability, accessibility, and cooperative responsibility must take first priority, and alongside this, ambitious and inclusive planning processes to move beyond economic and social cost (Appendix 9.7).

6.1.3 Manufacturers

The selection of manufacturers was a difficult procedure due to the availability of representatives from different manufacturing companies to participate in the interviews. The process of identifying the manufacturers, both national and international, resulted in a large list of companies, which, as a criteria, must have an existing presence in Denmark and in Bornholm. Firstly, companies of interest were contacted via email with a short explanation of the project and a request for an interview. The list of the contacted manufacturing companies includes the following: Bosch, Nibe, Grundfos, Viessmann, BDR Thermea Group, Danfoss, Ariston Thermo Group, Vaillant Group, Alfa Laval, Daikin, and MAN Energy, from these 11 companies, 2 of them replied and an interview was scheduled, 3 of them replied declined, while the rest of them did not respond at all.

The insights provided from the perspective of the two manufacturing companies, BDR Thermea Group and Alfa Laval are shaping the role of the manufacturers and their perspective for this project. The two companies interviewed are relevant and can provide insight into the heat pump sector. BDR Thermea represents a major manufacturer of residential heating systems in Denmark and the EU, offering a strong industry perspective on product life cycle and take-back potential. Although it does not specialize in residential units, Alfa Laval is a global leader in providing equipment in industrial heating and energy systems, while having a strong focus on circular economy practices.

What they do illustrates how the principles of eco-design, an underlying principle of eco-innovation theory, emphasize modularity and recyclability as the drivers of circularity. By disassembly design and tracking material consumption, manufacturers such as Alfa Laval and BDR Thermea facilitate systemic eco-innovation. Fjelkner said that the design of the product and the choice of materials play an important role in determining the feasibility of applying circular strategies (Appendix 9.4).

It was pointed out that whether applying circular strategies is feasible or not, it largely dependents on product design and the materials used (Appendix 9.4). Alfa Laval uses recycled rubber and metals in its manufacturing processes and engages with suppliers and recycling companies to maintain traceability and segregation of material flows. In addition, many of their products are constructed in modularity design, where components may be replaced, refurbished, and upgraded. But she noted that more modularity often means a loss of durability in extreme-stress applications, such as high pressure or high temperature (Appendix 9.4). Even though products last a long time (typically 25 to 60 years), the company has begun experimenting with take-back programs with the assistance of recycling firms, particularly in Europe (Appendix 9.4). Although promising, such systems are only in their infancy and are constrained by organizational and logistic barriers, such as tracking products at the ends of their useful lives when ownership will have shifted multiple times.

Regarding the advantages, Alfa Laval's own sustainability goals like lowering Scope 1 and Scope 2 emissions by 100% by 2027 and Scope 3 emission by 50% by 2030 are supported by circular practices (Appendix 9.4). Circular practices facilitate reducing dependence on virgin material and the carbon footprint of material extraction. In addition, the organization sees prospects for circular activities such as refurbishment since they can provide product's useful life enhancement while creating customer relationships through long-term service agreements and spare parts programs.

However, the challenges of the implementation of circular strategies remain, according to Ebba Fjelkner (Appendix 9.4). From an economic perspective, recycled materials would generally entail greater costs than virgin materials, and the demand in the market is not yet sufficiently established to justify the large-scale adoption of these materials. Secondly, the company is faced with impediments in communication since it occupies an intermediary role between the manufacturers and the real end users. This affects the company's ability to determine whether manufacturers have been given any feedback on the recovery or recycling of any of their products (Appendix 9.4). In terms of legislation, Alfa Laval's products may not fall directly under WEEE directives, given the absence of electrical and electronic components, although broader CSR reporting requirements and sustainability goals aligned with the Paris Agreement exert pressure to pursue circular improvements.

BDR Thermea acknowledges the relevance and potential of circular economy strategies, particularly regarding repairability, refurbishment and product life cycle tracking (Appendix 9.6). The company is already exploring repairability scoring systems, which could be based on hypotheses like average repair cost, component availability, and product downtime. Improved documentation, such as self-diagnostic routines and flowcharts for installers, is seen as a way to streamline maintenance and minimize errors. While there is no current infrastructure for tracking products post-sale, BDR Thermea is considering integrating connectivity features in future products to monitor performance and usage history (Appendix 9.6). However, such digital solutions are highly dependent on the demand of customers and the associated costs, which remain key decision-making factors.

The implementation of product recovery systems and recall strategies presents several logistic and structural challenges. One major issue is the lack of standardized packaging across suppliers, making reverse logistics inefficient and expensive. BDR Thermea sees promise in collaborative logistics loops, possibly coordinated by municipalities or recycling companies, to enable component recovery and refurbishment (Appendix 9.6). Yet, these systems require industry-wide cooperation and standardization to be cost-effective. The company is open to establishing a refurbishment center, but only if there is a sufficient and predictable flow of returned products, which is currently limited as many older heat pumps are just now entering recycling centers.

Economic factors and regulatory frameworks are considered decisive in the feasibility of circular approaches. BDR Thermea emphasizes that cost remains the dominant driver in consumer decisions, often outweighing sustainability concerns or the origin of the product (Appendix 9.6). Additionally, existing subsidy structures hinder alternative business models such as heat-as-a-service or leasing, since subsidies are typically available only for outright purchases. BDR Thermea believes that without policy alignment, such as incentives for circular practices, the adoption of circular strategies will remain limited due to the financial burden they currently impose on manufacturers.

The participation of manufacturers in exploring the tracking of the product life cycle aligns with the R1 to R6 strategies of the 9R framework and indicates a shift to circular business models such as product-service systems, another focus of the eco-innovation theory.

6.1.4 Installers

From the point of view of the installers on the island, there is valuable knowledge about the operational realities of handling heat pumps on Bornholm. The interviewed installation company indicated that although there is an adequate waste management system on the island with local recycling companies, there is no particular heat pump scheme or awareness of the handling of heat pumps from a circular perspective (Appendix 9.2). Unlike other product categories such as circulation pumps or toilets, where take-back and recycling by manufacturers are standard, heat pumps currently fall outside such organized schemes. For the feasibility of a take-back system for heat pumps in Bornholm, Hansen answers positively that a take-back system would be interesting for the installing company to participate, provided it is logistically straightforward and does not place additional time burdens on installers (Appendix 9.2). Installers fulfill a valuable intermediary role within the socio-technical system of circularity and represent the type of "niche actors"that systems innovation theory suggests have potential to disrupt incumbent practices through their proximity to end-users and technical knowledge. That he emphasizes the precedence of environmental incentives over financial incentives suggests an eagerness within the industry to support sustainability efforts if the right infrastructure and support systems exist (Appendix 9.2).

Installers, according to Hansen, have the key role to play in ensuring circularity, as they are the ones directly dealing with the end customers and are a crucial intermediary in the supply and replacement chain (Appendix 9.2). From their perspective, there are real benefits in putting circular strategies to work in the heat pump sector, specifically with respect to the environment. According to him, since installers stand between manufacturers, retailers, and consumers, they are the ones who can foster the reduction of the environmental footprint attributed to HVAC systems (Appendix 9.2).

Despite the benefits that Hansen mentions, he highlights the challenges that can arise from the implementation of circularity. The most pressing of these is the lack of time and capacity among installers to handle the logistics of a take-back system (Appendix 9.2). Without additional support or clearly defined procedures, installers cannot adapt to existing models of circularity of heat pumps. He noted that awareness of the state-of-the-art knowledge around heat pump circularity is low within the community of installers, which draws attention to better communication among stakeholders, visibility, and training for the installers (Appendix 9.2). Although financial incentives are not a challenge for installers, based on the perspective of Hansen, he believes that environmental incentives could facilitate installer participation in a future take-back framework.

6.1.5 Retailers

Retailers of heat pumps, such as A&O Johansen, play a significant intermediary role in the supply chain, connecting manufacturers with professional installers and end users. Currently, the feasibility of implementing circular strategies among heat pump retailers is low, especially when it comes to take-back, repair, or recycling systems. As highlighted in the interview with A&O Johansen, the company strictly focuses on sales and offers minor repair and resale options for new, slightly damaged units, without warranty (Appendix 9.3). However, it does not accept used units for return or recycling, citing logistic and storage limitations as key barriers. Smaller retailers and wholesalers operating in Bornholm and similar regions typically follow similar models, focusing on efficient distribution rather than reverse logistics (Appendix 9.3). The infrastructure and business incentives to handle waste heat pumps at the retail level are not yet mature, making the implementation of circular models technically and economically difficult in this part of the value chain.

The potential benefits for retailers include differentiation through sustainable branding, alignment with upcoming regulations, and the opportunity to build service based revenue models. Furthermore, participation in producer-led take-back schemes could help retailers contribute to national and EU circular economy goals without bearing the full operational burden. The limited involvement of retailers with reverse logistics reflects a challenge within both the eco-innovation and the systems innovation frameworks: the absence of incentives, policy alignment, and integrated supply chain models necessary for the adoption of innovation across the value chain. Retailers could also benefit indirectly through customer loyalty and partnerships with manufacturers and installers who are under increasing pressure to provide life-cycle services.

However, there are substantial challenges in the implementation of circular strategies for retailers. As the case of A&O Johansen illustrates, most retailers lack physical space, technical capacity, and incentives to collect and store used units (Appendix 9.3). In addition, there presently exists no clear regulatory force or economic mechanism that will force or assist retailers to reverse logistics. Fragmentation of responsibilities between producers, installers, and recyclers places into question who is really supposed to manage the end-of-life phase (Appendix 9.3). Another challenge stems from the presence of products lacking circular designs; thus, the retail side finds it challenging to decide if a returned unit should be repaired and refurbished or taken for dismantling. In the absence of standardized systems and coordination throughout the value chain, most retailers will opt for linear models focused on fast turnover and minimal after-sale engagement.

6.1.6 Recycling Companies

The transition to a circular economy is not only a promising future but also a complex challenge for recycling companies. There are existing recycling companies in Denmark that show how the recycling sector is positioned in the middle of circular value chains. Such circular economy models can be technically and operationally executed by numerous recycling companies, especially in economies like Denmark where regulation, infrastructure, and market incentives are relatively sophisticated. Business organizations like H.J. Hansen already possess the material handling skills, logistics facilities, and business alliances in order to support materials recovery and recycling and reinsertion into new production cycles. Furthermore, digitalization and technological innovation in processing and sorting technologies are enhancing the efficiency and scalability of high-quality recycling. Such technological innovation is complementary to the R8 strategy (Recycle) in the 9R hierarchy but also enhances the need for upstream coordination and eco-design to facilitate higher-order strategies including refurbishment and remanufacturing. From a systems innovation perspective, recycling companies are regime level stakeholders who can induce or inhibit circular transitions depending on market and institution variables.

Their adoption helps to create new revenue streams from resale of recycled materials as well as business model innovation as service-based or product-as-a-service offerings. From a compliance and regulatory standpoint, the use of circular strategies can help improve compliance with tightening EU directives on waste, aid corporate ESG goals, as well as improve public reputation. Despite the potential benefits that the implementation of circular strategies have, recycling companies can face critical challenges. The first and foremost for all the private companies is economic viability, which focused on the costs of collecting, sorting, and processing materials. Another challenge is the product design, due to the fact that many products in the heat pump sector are not designed with disassembly, recyclability or reuse in mind, limiting the effectiveness of downstream efforts.

6.1.7 End-users

Although no interviews were conducted with end-users in this study, their role in the circular transition of the heat pump sector remains essential. For the feasibility, end-users can be active participants in circular strategies such as repair, refurbishment, and recycling, especially when a system such as take-back schemes or service providing contracts are well communicated and easily accessible. The primary benefits for end-users include an extended shelf life of the product, potential cost benefits from refurbished equipment, and the opportunity to contribute to sustainability goals. However, the challenges include the lack of awareness about circular options, limited incentives to return used products, and logistical burdens such as disassembly or transportation. Ensuring a user-friendly and economically appealing system is the key to activating their role in the circular economy.

6.1.8 Danish Energy Agency

Although SparEnergi, which is under the Danish Energy Agency, does not directly handle services such as recycling or removal of heat pumps, their role as a public information and advisory platform contributes to the broader awareness and promotion of circular strategies in Denmark (Appendix 9.5). According to the response received, the feasibility of implementing a take-back or refurbishment system depends heavily on regulatory frameworks, environmental benefits, and product performance over time (e.g., SCOP and COP values). Public institutions like the Danish Energy Agency could play a critical role in initiating regulations and supporting cost-benefit assessments. Although potential benefits include improved resource recovery and environmental gains, challenges include the complexity of refurbishing older units containing outdated or illegal refrigerants and the need for strong collaboration with producers, municipalities, and policy makers. Thus, their role is less operational and more strategic, laying the groundwork for future systems through research, policy development, and communication.

Danish Energy Agency can support circular strategies for heat pumps by developing national guidelines on refurbishment and reuse, in collaboration with industry and municipal actors. They could initiate pilot take-back schemes with local authorities, such as BOFA, to test and scale practical models. Additionally, Danish Energy Agency could create training programs for installers and expand public awareness campaigns to include responsible end-of-life management. Finally, they can advise on policy development and advocate for funding mechanisms that support refurbishment and recycling initiatives across Denmark.

Stakeholder	Feasibility	Perceived Benefits	Main Challenges
Local Authorities/ BOFA	Moderately feasible; dependent on funding and policy tools	Reduced waste, public sector leadership in circularity	Limited budgets, unclear regulatory support
BEOF	Feasible as part of energy and infrastructure planning	Grid stability, energy efficiency, regional innovation	Integration complexity, stakeholder alignment
Manufacturers	Technically feasible for modular designs; costly to implement	Brand value, potential for product-as-a-service models	Cost of redesign, lack of infrastructure for returns
Installers/Technicians	Feasible with training and support	Increased service revenue, extended system lifespan	Lack of spare parts, technical complexity
Retailers	Conditional feasibility based on supply availability	Customer loyalty, differentiation in market	Pressure on margins, lack of circular-ready products
Recycling Companies	Feasible if product design is standardized	More recoverable materials, efficiency in waste processing	Current products hard to disassemble or identify materials
End-Users	Low feasibility unless guided or incentivized	Lower long-term costs, improved maintenance access	Limited knowledge, upfront cost sensitivity
Energy Agency of Denmark	Nationally feasible; requires coordination with regions	Alignment with climate targets, innovation in energy tech	Fragmented implementation, data gaps

Figur 6.1. The stakeholders in relation to the feasibility, perceived benefits and main challenges on the implementation of the circular strategies (Own figure)

6.2 Demands of the take-back system

Adopting circular economy approaches offers a promising direction for managing the future of heat pumps, particularly regarding their end-of-life phase. As discussed in Chapter 4, the 9R framework serves as a practical guide to move from traditional linear models to more circular systems. One mechanism that can support this shift is the take-back system, which involves returning used or malfunctioning heat pumps to designated collection points, either for repair or final disposal. This model promotes resource recovery and extends the useful life of components, aligning with circularity objectives.

When developing a take-back system, certain design requirements must be addressed to ensure the system effectively supports the shift from a linear to a circular economy. These requirements establish specific criteria that must be fulfilled for the take-back model to be successful and aligned with the principles of sustainability and innovation.

Regulatory demands
Ensuring regulatory compliance is a key consideration in the development of take-back systems. The Waste Electrical and Electronic Equipment (WEEE) Directive plays a central role in outlining how heat pumps should be collected, recycled, and disposed of to reduce environmental harm. It also helps shape the structure of take-back systems by defining responsibilities among stakeholders and outlining funding and management mechanisms. In addition, the principle of Extended Producer Responsibility (EPR) places the obligation on manufacturers and importers to take responsibility for the entire life cycle of heat pumps, reinforcing accountability and promoting more sustainable practices.

Environmental demands
Another essential requirement in designing an effective take-back system is ensuring alignment with broader environmental and sustainability objectives. By emphasizing circular practices such as recycling and reuse, take-back systems can directly contribute to fulfilling the targets set by the EU Green Deal and the Circular Economy Action Plan. These systems not only help reduce the environmental impact but also support innovative waste management initiatives, such as those currently being implemented in Denmark.

Stakeholder demands
The effective implementation of a heat pump take-back system relies heavily on strong collaboration between stakeholders. Coordinated participation of various groups, including government bodies, NGOs, and policy makers, is essential to developing a functional and impactful system. Each stakeholder brings unique experience, contributing to system design, governance, and public participation. Fostering inclusive and productive partnerships not only helps set new standards in the heat pump market but also promotes consumer awareness and behavioral change. This collective effort improves system performance, encourages innovation, and reinforces shared responsibility, in line with Denmark's goals for sustainability and a circular economy.

Economic demands
The economic dimension is a crucial component in the development of a successful take-back system. For such a system to be viable, it must be supported by effective funding strategies and demonstrate cost-efficiency. Beyond its environmental benefits, the economic case often influences whether governments will allocate financial support through subsidies or incentives. Ensuring cost-effectiveness involves optimizing logistics, building scalable infrastructure, and streamlining operations to minimize expenses without placing undue financial pressure on manufacturers, recyclers, or consumers. Achieving this balance is the key to the long-term success of the system and its alignment with Denmark's goals in the environment and circular economy.

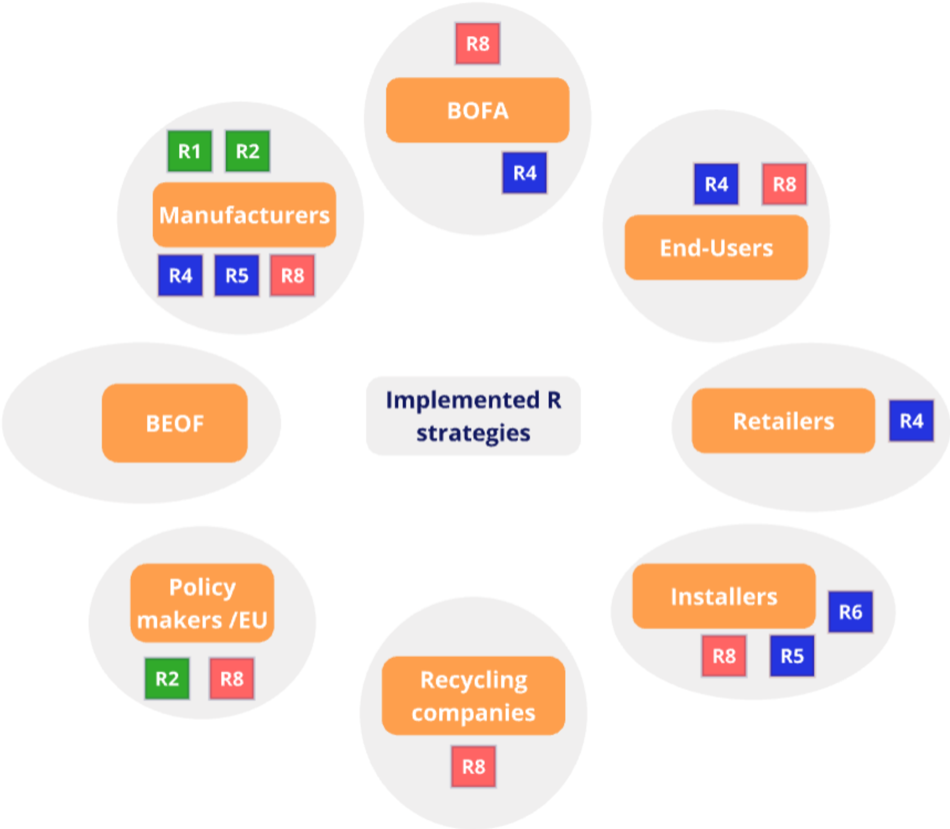
Demands for heat pump take-back system			
Regulatory demands	**Environmental demands**	**Stakeholder demands**	**Economic demands**
EPR compliance	Green Deal	Coordination & collaboration between experts	Cost-effectiveness
WEEE Directive compliance	Alignment with the environmental & sustainability goals	Contribution of the heat pump market and raise of awareness	Avoiding excessive financial burdens
	Circular Economy Action Plan		Maintaining affordability

Figur 6.2. Demands of the take-back system (Own figure)

An overview of the key demands of the take-back system is illustrated in Figure 6.2. The figure highlights the main demands outlined in Section 6.2, organized by category to enhance readability and provide a clear summary for the reader.

6.3 The implementation of the 9R's in the heat pump sector

The current situation of the heat pump sector in Bornholm, but also in Denmark, based on how it was presented from the stakeholders of this analysis, presents the opportunities and potentials of the 9R strategies that are already being implemented. This section provides a model of today's take-back model, in the case of its existence, based on the perspective of the stakeholders and the actions that aligning with the 9R practices. The figure 6.3 visualizes the system in hand and which of the 9R strategies each of the stakeholders are familiar with.



Figur 6.3. The present implementation of the 9R strategies (Own figure)

At the lowest level of the 9R hierarchy, the R9 strategy involves recovering energy from discarded products. However, this approach is not applicable to heat pump take-back systems, as incineration, which usually is used for energy recovery, is not a feasible or appropriate method for disposing of heat pumps and there is not a mention from the interviewed stakeholders for use of this strategy.

The **R8 strategy**, which refers to recycling of heat pumps, is the one strategy that appears the most, and it has been applied regularly for heat pumps in Bornholm due to different factors. One of the first factors that apply to the case of Bornholm is its agenda of zero waste island by 2032, in which is included the goal of recycling scheme of electronic waste (Appendix 9.1). Recycling WEEE is among the EU directives for waste management which Bornholm follows. Recycling aligns with the goal of zero waste, while the circularity goals of Bornholm are supported by ensuring that components of discarded heat pumps are recycled rather than sent to landfill.

Also, recycling is often regarded as the most straightforward solution for managing discarded heat pumps, largely because of a lack of specialized technical expertise in repairing, refurbishing, or remanufacturing these systems. BOFA express concerns not about the lack of expertise in the island, but rather the regulations around the need of a certified technician to handle the higher circularity processes (Appendix 9.1).

BOFA pressures the fact that the material recycling of the e-waste according to Bornholm's vision, is not following the true sense of circularity, as they collect e-waste on collection centers, but they legally claimed by EPR organizations, blocking BOFA from handling them or redirecting them for reuse (Appendix 9.1).

From the installers perspective, recycling is already a practice that take part in for old or non-functional heat pumps, since they are partnering with a local recycling dealer who picks up the units. This indicates that basic recycling infrastructure is already in place, although not within a structured take-back system.

From the retailer perspective, the only recycling practice they have is for packaging at the moment and they are not having any actions relating to heat pump recycling.

One of the manufacturers emphasizes recycling as a key component of its circularity strategy by integrating recycled metals and rubber into product manufacturing and designing heat exchangers for easier disassembly and material recovery (Appendix 9.4). The company collaborates with recycling firms to enable customers to return old equipment, offering potential benefits in exchange. They also act as intermediaries, connecting customers with recyclers rather than managing collection directly (Appendix 9.4). The second manufacturer points out that recycling and eco-design are progressing but are largely driven by evolving EU regulations rather than internal market dynamics (Appendix 9.6).

The Danish Energy Agency currently does not offer direct recycling or end-of-life services for heat pumps, as this responsibility lies with manufacturers and municipal recycling systems.

Strategies higher in the circularity array, as the **R5: Refurbish, R6: Remanufacture and R7: Repurpose strategies**, are also limited because of restricted regulations from EU about the EEE waste management.

Currently, BOFA does not accommodate any actions that are aligning with the repurpose strategy or an active system in place on Bornholm for repurposing heat pumps. While initiatives like the REuseLAB Bornholm project have explored circular solutions for other appliances, such as refrigerators and freezers, the repurposing of heat pumps remains a prospective opportunity rather than an established practice (Appendix 9.1). The same issue applies for the other two strategies, R5 and R6, the Refurbish and Remanufacture strategies respectively. From the perspective of installers, there is currently no structured process for heat pump repurposing, remanufacturing or refurbishing, although the installer is familiar with similar systems for products like circulation pumps and toilets.

Also, from the side of manufacturers, there is no active scheme that implements any of the aforementioned strategies, while they find there are potentials on the future. The same applies for all the stakeholders, that do not have any particular actions towards these strategies, while they are interested in being part on an innovative system that implements them under the right circumstances.

The **R4: Repair strategy** is already being applied to similar products in Bornholm through initiatives led by BOFA. Notably, innovative projects have emerged from the collaboration between FGU Bornholm, the appliance company SA-Service, and BOFA. These efforts have resulted in the development of educational materials focused on repair techniques, sustainability, global resource awareness, and energy labeling. Despite the promise of such initiatives, applying them to heat pumps remains challenging due to regulatory restrictions (Appendix 9.1).

BDR Thermea integrates repairability into its heat pump design by focusing on modular construction and easier access to spare parts, supported by internal repairability indices, though these are not yet standardized or public (Appendix 9.6). Alfa Laval highlights that the company actively supports repair and refurbishment as part of its circular strategy. Through long-term service agreements, some lasting up to 60 years, the company provides spare parts, performance checks, and maintenance to encourage customers to repair rather than replace equipment (Appendix 9.4). While repair is generally preferred for environmental reasons, Alfa Laval also evaluates whether a new unit might be more sustainable in specific cases. The decision between serviceable or compact-efficient units is made based on customer needs and application type, showing a flexible and customer-oriented approach to repairability and refurbishment.

In the case of the retailer, there is one option of repair and that includes only the new heat pumps. If there is a heat pump that is not applying in the standards of a new unit, they will repair it and resell it in a reduced price without a guarantee.

The end-users are part of the Repair strategy as they are the ones that demand it as they have a claim in the product in the first place. Either this is their only option, or they are keen to circularity, the Repair strategy is being implemented by them, as it is seen from their interactions with the other stakeholders.

The **R3: Reuse strategy** centers on extending the life of discarded heat pumps by redeploying them in lower-tier markets, provided their functionality is preserved. While some expired units could potentially be reused by their original manufacturers, this approach faces significant regulatory hurdles. Specifically, reuse may conflict with existing heat pump waste management guidelines and the obligations imposed by EPR, which can limit the viability of this strategy within the current regulatory framework. There are not active schemes of reusing heat pumps from the perspective of the stakeholders at this moment, although there is an expression of interest from BOFA to make it happen.

The **R2: reduce strategy** is more aligned with the manufacturers' practices, as it is a strategy that is implemented to design more efficient heat pump units for the market. Alfa Laval's sustainability strategy strongly focuses on the "reduce" principle, aiming to cut 100% of Scope 1 and 2 emissions by 2027 and 50% of Scope 3 emissions by 2030, with a goal of net-zero by 2050 (Appendix 9.4). Since most of the company's emissions come from materials rather than energy-intensive processes, reducing the environmental impact of materials is crucial. These reduction efforts are driven not only by internal sustainability goals aligned with the Paris Agreement but also by increasing pressure from EU regulations and corporate responsibility standards.

The interview with BDR Thermea Group reveals that the company's circular economy strategy incorporates key elements of the Reduce strategy, particularly through its eco-design efforts. These include using modular components, recycled materials, and designing for disassemblability, which collectively aim to reduce raw material usage and environmental impact (Appendix 9.6).

The impact of the EU regulations and policies, while the existing Scope are in active consideration, places the EU and policy makers as stakeholders in the reduce strategy. Reducing the emissions and the use of raw materials, while implementing the directives that are universal for the companies and aligning with EU's SDG goals is also part of the reduce strategy.

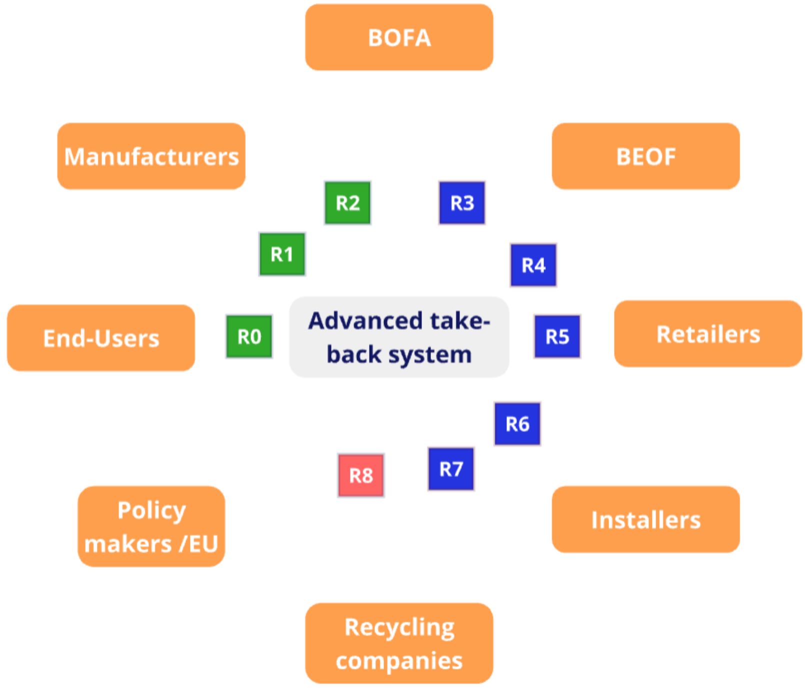
The **R1: rethink strategy** also aspires more to the manufacturers, which focuses on designing of the heat pump. The rethink strategy is reflected in BDR Thermea Group's approach through their integration of eco-design principles early in the product development phase, prompting a fundamental reconsideration of how products are designed, used, and serviced (Appendix 9.6). This includes rethinking product design to allow easier disassembly, maintenance, and future upgrades, which aligns with long-term circular goals. The company is also rethinking its role in the value chain by collaborating with recyclers and exploring service-based models like take-back systems, although these are not yet fully implemented.

Alfa Laval demonstrates a strong rethink approach by incorporating circular principles from an early point in the product design phase. Ebba Fjelkner explains that the company deliberately considers material selection, durability, and recyclability from the very beginning, for instance, by streamlining metal thickness to reduce material consumption without compromising performance (Appendix 9.4). The sign of a deliberate move away from a single end-of-life focus, such as take-back programs, towards rethinking how products are designed with a top-of-mind circularity as an overarching design goal.

The **R0: Refuse strategy** presents a contradiction to current EU action plans, which actively promote the adoption of heat pumps due to their high energy efficiency compared to conventional heating systems. This strategy emphasizes avoiding unnecessary consumption and curbing the overproduction of new devices, including heat pumps. A notable example highlighting the challenges of this approach comes from a heat pump supplier, which reported that units nearing their expiration date are withheld from sale. This has led to a growing stockpile of unsold, expired heat pumps, with no clear strategy in place for managing them within the supply chain.

6.4 A future perspective of the take-back system for heat pumps in Bornholm

In this section, an advanced take-back system for heat pumps is recommended, combined with the circular economy strategies. Considering the perspectives of the stakeholders that were interviewed and the potentials of the 9R strategies, there is a recommended system of how these strategies can be intertwined with the actions of stakeholders and create an agenda of the take-back system for heat pumps in Bornholm. The figure below is showcasing each stakeholders and the potential strategies that could implement in their agenda to ensure a transition towards circular economy.



Figur 6.4. An advanced model of future take-back system (Own figure)

Beginning at the top of the hierarchy illustrated in Figure 4.2, there are the three first strategies that have better application from the perspective of the manufacturers and the producers. The first strategy with potential for future implementation within the take-back system is R0: Refuse. The Refuse strategy adheres to the reduction of the unnecessary production of products that have an environmental impact, while focusing on the source of the problem. This particular strategy in a real world scenario will not appeal to the manufacturers and the production chain altogether, since its goal is against the business model of the producing companies. Although there are actions in both the interviewed companies that aim to refuse the use of excessive materials. such as the example of Alfa Laval and the metal thickness, and the incorporation of the eco-design directive, such as the leading efforts from BDR Thermea to design based on the Eco-design.

The R1 : Rethink strategy is the main strategy that is used when redesigning a product to comply with efficiency, multifunctionality and resource use. The process of designing for the manufacturers of heat pumps is complex, due to the different components and variety of materials that are in a heat pump unit. Although the complexity, manufacturers can implement in their process the Rethink strategy for material use, modularity, durability, disassemblability, and repairability. The Eco-design integration can be a competitive tool for the companies that work in manufacturing, since they provide environmental benefit and set them as pioneers in the circularity landscape. Also, the early attention to the waste production is the designing for the end-of-life products to not be waste, but something useful through process or return in the production system, like a take-back. Rethinking the business model and how they can create value in the supply chain that they are part of is also part of the implementation of the circular strategies in the heat pump sector.

From the EU perspective, new business models that are not in the market, or they are not engaging enough, should be more supported either financially, or with directives that companies can follow, such as the the Eco-design directive.

The third strategy, the R2 : Reduce strategy, can be implemented in similar way as the previous two for the manufacturers and the take-back system. For both manufacturers and consumers, there should be greater emphasis on encouraging heat pump producers to extend product lifespan, thereby minimizing material consumption. Additionally, integrating the take-back system into product design can enable the reuse of components from discarded units, reducing reliance on virgin materials when producing new heat pumps. Depending on the stakeholder viewpoint, this approach aligns with multiple strategies within the 9R framework. In this case, manufacturers are the key stakeholders, as they stand to benefit by adopting more circular production methods that lower material costs and support sustainable innovation.

The second block of circular strategies, ranging from R3: Reuse to R7: Repurpose, can be directly integrated into a future take-back system as practical and actionable components. The R3: Reuse strategy can be incorporated into a future take-back system by establishing designated collection points for used, broken, or discarded heat pumps. Certified electricians could then assess and repair these units, either returning them to their original owners or reselling them. Implementing this strategy would require targeted training programs for local technicians, equipping them with the skills necessary for effective refurbishment and repair. The installers could be trained to retrieve the usable units from the end-users or retailers in the case of expired units. From the side of BOFA and BEOF, they can serve as reuse hubs in the island and be the leading managers for the take-back system. Additionally, public awareness campaigns could help increase participation and the volume of returned units. As with all strategies, appropriate regulatory frameworks should be applied to ensure that the reuse of heat pumps through a localized take-back system complies with safety and environmental standards. Moreover, Denmark's "Heat as a Service" (HaaS) model, supported by the Danish Energy Agency, can complement this reuse strategy by shifting ownership and maintenance responsibilities to service providers. In this model, companies have control over the full life cycle of the heat pump, allowing for systematic refurbishment, reuse, or proper disposal. Integrating HaaS into the take-back system would enhance circularity by ensuring that heat pumps are not only used efficiently, but also responsibly managed after decommissioning.

Similarly, the R4: Repair, R5: Refurbish, and R6: Remanufacture strategies can be integrated into the take-back system as the Reuse strategy. These approaches can benefit from parallel initiatives, such as technician training programs to have the knowledge to repair certain units, local incentive schemes for the citizens and to appeal to bigger companies, and the development of standardized procedures from the policy makers and EU. The key distinction between these strategies lies in the level and type of treatment applied to heat pumps at the end of their life cycle. Decisions regarding which strategy to pursue can be based on factors such as the unit's age, material composition, and overall repairability, which analyzed in the chapters below.

There is significant potential for repurposing individual components of heat pumps for use in other industries or applications, where they can serve different functions in entirely separate operations. Implementing an innovative take-back system staffed by experts capable of identifying the reuse potential of each component would align with the R7: Repurpose strategy. This approach not only extends the value of materials but also promotes cross-sectoral circularity by redirecting functional parts into new product streams.

The final two strategies, R8: Recycle and R9: Recover, are considered the least circular and should be regarded as last-resort options when designing an advanced take-back system. Although recycling is already practiced in Bornholm, it currently operates outside the scope of a structured take-back framework. Integrating recycling into such a system could enable the creation of a coordinated network linking key stakeholders, including installers, end-users, and manufacturers, through centralized collection points for discarded heat pumps. Effective collaboration among these actors will be essential to ensuring the system's overall success and efficiency.

In the case of Bornholm, there is a need to upcycle end-of-life products like heat pumps. This could be achieved if BOFA is granted more flexible treatment by regulatory organizations, allowing them to experiment with circular supply chains. Also, there could be a funding initiative from NGO's or the government for the support of pilot mode for a take-back system. Such an approach could create greater value in the final products of recycling.

Recommendations for a future take-back system in Bornholm emphasize the integration of circular economy strategies with stakeholder engagement, while also addressing existing regulatory and operational barriers. A central recommendation is the launch of a small-scale pilot program for heat pump take-back, guided by the principles of the 9R framework. This pilot would serve as a testing ground to evaluate the system's practical limitations, identify areas for improvement, and assess overall feasibility. Positive outcomes from such an initiative could contribute to shaping future regulatory developments, encouraging broader adoption of circular practices across the sector.

6.5 Stakeholder role in a take-back system

In the scenario of the implementation of the take-back system, the stakeholders that are involved must have predetermined tasks that align with their role and capabilities. One of the most critical factors for the success of the system is effective communication among stakeholders, which ensures coordination at all levels of operation. There must be a coordinator and project leader for coherence between stakeholders, and in the case of Bornholm, a potential collaboration between BOFA and BEOF can create a fruitful opportunity for the island to reach their zero-waste goal. BOFA could oversee operational aspects, such as logistics, sorting, and liaison with recyclers, while BEOF would support user engagement, data analysis, and strategic planning. Joint efforts could focus on creating an integrated database to track heat pump flows, assessing the feasibility of second-life options, and disseminating best practices. By aligning municipal waste management with energy efficiency strategies, Bornholm could serve as a living laboratory for Denmark's transition to a circular economy in the energy sector and the circular economy.

This mapping of stakeholder roles is informed by systems innovation theory, which emphasizes the importance of actor networks, institutional dynamics, and multi-level coordination in enabling sustainable transitions. By clarifying roles, the analysis aims to address the fragmented responsibilities that currently inhibit circular implementation, as identified by both BOFA and BEOF.

BOFA is strategically positioned to coordinate local take-back operations. Its infrastructure could be adapted to accept and temporarily store returned units, sort them according to condition, and direct them to appropriate downstream pathways, such as refurbishment, recycling, or safe disposal. BOFA's public mandate and existing logistics network make it an ideal actor to supervise the collection and redistribution of heat pumps.

In the figure below, there is a table depicting the tasks of the stakeholder for a take-back system and what their relation between them and BEOF could be.

Stakeholder	Tasks	Relevant 9R Strategies	Collaboration with BOFA & BEOF
BOFA	Acting as the central actor for collecting, storing, and directing EOL heat pumps on Bornholm.	Reduce, Reuse, Recycle	Partner with BEOF to match returned units with reuse opportunities
	Maintaining facilities for sorting and temporary storage prior to further processing.		
	Conducting awareness campaigns to encourage user participation in the take-back program.		
	Connecting the system's logistical and informational aspects to ensure smooth operation between recyclers and BEOF.		

Figur 6.5. List of tasks for BOFA in a take-back system for heat pumps in relation to the 9Rs (Own figure)

BEOF, Bornholm's energy utility, could contribute through energy audits, identifying underperforming systems, and advising consumers on circular options, such as replacement or system upgrades. BEOF could also integrate data monitoring tools to track system performance over time, thereby identifying ideal moments for interventions such as repair or replacement, and recommending suitable recovery strategies. Furthermore, it can promote participation in the take-back system by embedding circular information into customer communication and subsidy schemes.

In the figure below, there is a table depicting the tasks of the stakeholder for a take-back system and what their relation between them and BOFA could be.

Stakeholder	Tasks	Relevant 9R Strategies	Collaboration with BOFA & BEOF
BEOF	Identifying inefficient or outdated systems eligible for recovery or upgrade.	Rethink, Refurbish, Remanufacture	Use BOFA returns to supply a testbed for second-life systems
	Monitoring system performance to trigger timely maintenance, recovery, or replacement.		
	Promoting the use of restored heat pumps or offering discounts in partnership with manufacturers or BOFA.		

Figur 6.6. List of tasks for BEOF in a take-back system for heat pumps in relation to the 9Rs (Own figure)

The manufacturer's role is fundamental in the system, as they determine the design of the heat pumps. They are responsible for applying eco-design principles, such ar modularity, recyclability, and durability, while following the eco-design principles enables easier disassembly, repair, and upgrading of components. This is essential for the take-back system in the strategies of Reuse, Refurbish, and Remanufacture. Additionally, another task for manufacturers would be to track and trace their components, their product's history, or their product's repair status through a digital passport. Lastly, they could reintegrate the recovered parts and materials into new products, as part of their tasks, implementing lower-circularity strategies as it is the recycling.

In the figure below, there is a table depicting the tasks of manufacturers for a take-back system and what their relation between them and BOFA & BEOF could be.

Stakeholder	Tasks	Relevant 9R Strategies	Collaboration with BOFA & BEOF
Manufacturers	Design for circularity: Implement eco-design strategies that enable modularity, ease of disassembly, and component standardization. Trach and trace systems: Embed digital product passports. Component harvesting and remanufacturing: Reintegrate recovered parts and materials into new products.	Refuse, Rethink, Reduce, Refurbish, Remanufacture	Coordinate with BOFA/BEOF to retrieve data on failure rates and end-of-life units.

Figur 6.7. List of tasks for manufacturers in a take-back system for heat pumps in relation to the 9Rs (Own figure)

Retailers are intermediaries between manufacturers and end-users or installers. Their role can extend beyond mere sales to include logistical coordination of the take-back system. By offering collection points for obsolete heat pumps, advertising circular options, such as refurbished or second-hand heat pumps, and participating in reverse logistics, retailers can support strategies like Rethink and Reuse, while simultaneously raising consumer awareness of circular consumption models.

In the figure below, there is a table depicting the tasks of retailers for a take-back system and what their relation between them and BOFA & BEOF could be.

Stakeholder	Tasks	Relevant 9R Strategies	Collaboration with BOFA & BEOF
Retailers	Collection points: Provide facilities for customers to return end-of-life units during new purchase or maintenance. Costumer education: Inform buyers about available take-back services, refurbishment options, and sustainable disposal. Participation in reverse logistics: Connecting users or installers with recyclers or refurbishers.	Rethink, Reduce, Reuse	Serve as collection partners with BOFA for local returns

Figur 6.8. List of tasks for retailers in a take-back system for heat pumps in relation to the 9Rs (Own figure)

Installers also play a crucial role in the system due to their technical expertise and immediate contact with installed units. They are certified technicians with the ability to understand whether a unit is to be discarded, recommend timely repairs or upgrades, and ensure compliance with manufacturer guidelines for safe disassembly. In a take-back system, installers could be promoted to collect used units during replacements and to provide them to appropriate reuse, refurbish, or recycling pathways, with their expertise knowledge.

In the figure below, there is a table depicting the tasks of installers for a take-back system and what their relation between them and BOFA & BEOF could be.

Stakeholder	Tasks	Relevant 9R Strategies	Collaboration with BOFA & BEOF
Installer	On-site collection: Retrieve end-of-life units during replacement or service visits.	Reduce, Reuse, Repair	Report units suitable for reconditioning to BOFA/BEOF
	Safe disassembly: Remove systems without damaging recoverable components or releasing harmful refrigerants.		
	Feedback loop: Provide practical insights to manufacturers about design and reuse barriers encountered during disassembly.		

Figur 6.9. List of tasks for installers in a take-back system for heat pumps in relation to the 9Rs (Own figure)

Private recycling companies are responsible for the material processing stages of the system. These companies have the technical capacity to safely handle refrigerants, recover valuable metals, and ensure compliance with environmental standards. Their task involves dismantling units, separating hazardous components, and maximizing the recovery of materials for Recycling and Recovery. To improve efficiency, these firms can collaborate with manufacturers to establish closed-loop recycling systems that reintroduce recovered materials into new heat pump production.

In the figure below, there is a table depicting the tasks of private recycling companies for a take-back system and what their relation between them and BOFA & BEOF could be.

Stakeholder	Tasks	Relevant 9R Strategies	Collaboration with BOFA & BEOF
Private recycling companies	Dismantling units, recovering metals, and safely managing hazardous substances, such as foam and refrigerants.	Repurpose, Recycle, Recover	Work with BOFA to optimize recycling flows and compliance
	Ensuring compliance with environmental standards and offer verifiable recycling performance data.		

Figur 6.10. List of tasks for private recycling companies in a take-back system for heat pumps in relation to the 9Rs (Own figure)

End-users are essential actors whose participation determines the viability of circular flows. Although their role is largely passive, well-educated choices such as mend over replace, returning end-of-life devices to authorized collection points, and maintaining systems correctly are crucial to enable circular outcomes. Active participation by end-users is emphasized in ecologized innovation theory, namely through the application of user-oriented models of innovation. Their involvement can also cause the deployment of schemes like Reuse and Repair, as foreseen under the 9R approach.

In the figure below, there is a table depicting the tasks of end-users for a take-back system and what their relation between them and BOFA & BEOF could be.

Stakeholder	Tasks	Relevant 9R Strategies	Collaboration with BOFA & BEOF
End-users	Voluntary participation: Return old heat pumps to designated collection points or accept installer pick-up.	Refuse, Reuse, Repair	Engage with BOFA's drop-off system and BEOF energy audits
	Maintain equipment to prolong lifespan and make reuse more viable.		
	Informed choices about refurbished or upgraded models when possible, contributing to demand for second-life products.		

Figur 6.11. List of tasks for end-users in a take-back system for heat pumps in relation to the 9Rs (Own figure)

Legislative authorities can contribute to shaping the legal framework that puts in motion circular systems. These bodies are tasked with enacting policies that mandate product take-back, ensure safe handling of refrigerants, and provide incentives for circular business models. Moreover, they can facilitate pilot programs in locations like Bornholm and support public-private partnerships to ensure scalability and compliance with EU circular economy targets.

In the figure below, there is a table depicting the tasks of legislative authorities for a take-back system and what their relation between them and BOFA & BEOF could be.

Stakeholder	Tasks	Relevant 9R Strategies	Collaboration with BOFA & BEOF
Legislative Authorities	Creating regulatory frameworks that mandate take-back systems and ensuring compliance with EU directives.	Refuse, Reduce, Recycle	Provide policy framework enabling BOFA/BEOF pilot on Bornholm
	Offering financial incentives for refurbishment, recycling, and reuse initiatives.		

Figur 6.12. List of tasks for legislative authorities in a take-back system for heat pumps in relation to the 9Rs (Own figure)

In summary, a successful take-back system in Bornholm is based on clearly defined stakeholder roles, strong coordination, and aligned efforts between BOFA, BEOF, and other actors. Through collaboration and shared responsibility, the island can move closer to its zero-waste goals while serving as a model for circular practices in Denmark's energy and waste sectors.

To ensure effective and timely implementation of a take-back system, it is essential to involve individuals and institutions with decision-making authority from the early stages of planning. Authorities such as local policymakers, regional waste management leaders, such as BOFA, energy agencies, like the Danish Energy Agency, and public utility managers, like BEOF, possess not only the regulatory power but also the networks and financial levers to influence systemic change. Implementation can be accelerated if people with a certain authority support the new system, enabling policy alignment, securing funding, and integrating circularity goals.

6.6 Take-Back system proposition

In order to design an effective take-back system for heat pumps in a small-scale island context that applies the 9R framework as a guiding principle, a proposition for a guiding system is proposed. This guide aims to help with the collection and categorization of heat pumps. Each recovered heat pump is evaluated in condition and put into the most appropriate R-strategy: Reuse (R3) if the unit is still operating, Repair (R4) if it has minor flaws, Refurbishment (R5) for operating but obsolete units, or Remanufacturing (R6) if the components can be salvaged and put back together again. Repurposing (R7) is reserved for components that cannot be utilized anymore for their initial function, and recycling (R8) is the last material recovery action. Energy recovery (R9) through waste burning is treated very ruthlessly as the last option and is not a preferred solution.

By incorporating 9R strategies into the co-design process with stakeholders including manufacturers, users, installers, and recycling companies, the system aims to prioritize higher-order circular strategies and minimize the loss of resources. This does take into consideration the unique limitations of small islands, such as few recycling facilities and significant transport costs, and tries to retain maximum value locally while also minimizing environmental impact.

Condition	**9R Strategy**	**Action**
Fully working	**R3** Reuse	Test & resell
Minor fault	**R4** Repair	Quick fix
Outdated model	**R5** Refurbish	Upgrade parts
Broken but salvageable	**R6** Remanufacture	Dismantle and rebuild
Partly useful	**R7** Repurpose	News uses for parts
Materials only	**R8** Recycle	Material recovery
No other option	**R9** Recover	Waste-to-energy

Figur 6.13. List of sorting criteria for the future take-back system in Bornholm (Own figure)

The decision-making process for the sorting of returned products is designed collaboratively, ensuring that the practical knowledge of stakeholders and community-specific needs are incorporated to create a resilient and context-sensitive circular system.

6.7 Circularity potential for heat pumps on Bornholm through two scenarios

To explore the practical implications of stakeholder collaboration and co-design in establishing a circular system for heat pumps on Bornholm, two contrasting scenarios were developed. These scenarios help highlight the systemic barriers and incentives within the current socio-technical circumstances of the island.

Scenario 0: No action scenario
In this scenario, no significant measures are taken to transition to a circular economy in the management of heat pumps on the island of Bornholm. The stakeholders involved on the island around the heat pump sector continue to operate independently, without coordination or shared systems for end-of-life heat pump handling. Old units are typically removed by installers and discarded through conventional waste streams, or they are classified as WEEE and are taken from certified recycling companies for handling. BOFA, BEOF, installers, manufacturers, retailers,

and recycling companies each follow their individual tasks without structured collaboration and communication, while the product is following the stream of production and consumption.

The end-users and mainly the installers will not have access to new knowledge and sustainable practices, or tools for circular handling of heat pumps. Installers will not be considered as an important stakeholder for the transition to circular economy, despite the fact they can have a crucial role in the implementation of circular practices due to their technical skills in technology. This will result to most heat pumps to be removed by installers and sent directly to recycling or waste streams without assessment for reuse, repair, or refurbishment.

Furthermore, the environmental impact of the increasing production of heat pumps, without a plan for circular handling of the product, is considerable. Valuable components such as copper, aluminum, refrigerants, or high-grade plastics are downcycled or lost, while the greenhouse gas emissions associated with the extraction of virgin materials and the production of new products continue. This continuation, without pressure from the stakeholders in the sector, does not create pressure on the legislative authorities, as there are no bottom-up planning initiatives to take into account active plans that implement circular principles. The fragmented landscape results in limited material recovery, loss of critical resources, such as aluminium, refrigerants, and copper, and minimal feedback to manufacturers or policymakers. From a 9R framework perspective, this scenario remains confined to the lowest-value strategies, Recycle and Recover, neglecting higher-value loops such as Reuse, Refurbish, or Remanufacture.

Scenario 1: Collaborative take-back system for circular heat pumps

In this proactive scenario, a coordinated, multi-stakeholder take-back system is co-designed and implemented in Bornholm. It aims to transition to circular economy practices in the heat pump sector, with a bottom-up planning through stakeholder alignment, reverse logistics, and circular strategies inspired by the 9R framework, particularly the high-circularity strategies like Reuse, Repair, Remanufacture, Repurpose and Rethink, Refuse, Reduce.

The synergy between the stakeholders, BOFA leading the logistical and operational efforts while BEOF supporting strategic integration into the energy transition, can be highlighted in the active plans of Bornholm for sustainable development. From the perspective of the manufacturers, they are willing to redesign their products for modularity and traceability, since there is a system that can provide for them materials and data about their products after they leave their production line. Installers in this scenario act as points of connection with the end-users about information for their needs in the heat pump sector, but also as points of return and circular handling. Retailers have the similar role in the system in the perspective of information and raising awareness for the end-users, while they can deal with collection points for the recycling companies.

There will be activation for different circular pathways, from implementing Reuse strategies for functional units and Repair strategy for minor faults in units to be repaired locally, to Refurbish of obsolete functional systems and Remanufacture of salvaged parts. In the last resort of actions, the unusable components of the heat pumps can be repurposed for different products and services or they can be recycled from private recycling companies.

In regard to installers, they are specifically trained on circular processes and incentivized to participate either for their own benefit or for their environmental awareness. This creates a chain reaction for end-users to be informed and encouraged to engage to the system, because of either economic incentive or return policy.

In the economic side of the take-back system, there will be more local jobs for people to work in repair and refurbishment for heat pumps, while the attention of a working take-back system can capture funds of external programs that aim to circularity and are interested in working with Bornholm. For the manufacturers that will participate, there are the benefits of saving material and reducing CO emissions, and building a stronger relationship between the customers (end-users, installers, retailers). Last but not least, in relation to the EU directives that exist on the European landscape now, an implemented system that aims to high circularity strategies can enhance the compliance with these directives and be a frontier of the transition.

The following figure shows the comparison between both scenarios and the dimension that affects, from the stakeholder collaboration to the economic value.

Dimension	Scenario 0	Scenario 1
Stakeholder collaboration	Fragmented	Coordinated and integrated
Product design	Linear, non-modular	Modular, traceable, repairable
Take-back system	Non-existent	Centralized and co-managed
Installer involvement	Disposal-focused	Circular actor in collecting and repair
End-user role	Passive, unaware	Engaged and informed
Material fate	Downcycling or disposal	High-value recovery through circular routes
Regulatory compliance	Reactive, minimum standard	Proactive, leading in EU alignment
Environmental outcomes	High resource loss, emissions	Reduced waste, emissions, and raw material use
Economic value	Lost opportunities	Local job creation, service innovation

Figur 6.14. Comparison between the two scenarios (Own figure)

6.8 KPIs and future outlook

For the success of the implementation of the take-back system in Bornholm, the consideration of time and indicators are important. While the foundational steps, such as the stakeholder alignment, take-back system design, and the extensive research, towards creating a system are crucial, the success of the system depend on long-term testing and structured evaluation. To ensure progress of the system, a set of key performance indicators (KPIs) is developed for the project based on the system of the EC (European Commission , 2011).

The figure presents the suggested KPIs for the take-back system while explaining their objective and target. This categorization is helpful for better understanding and can be used in the future in the case of implementation the take-back scheme.

KPI	Objective	Measurement Method	Target
Heat pump collection rate	Ensuring extensive return of used heat pumps	% of discarded heat pumps returned	≥ 80% return rate in 5 years
Circular Reintegration Rate	Maximize reuse, repair, refurbish, and remanufacture	% of collected units redirected to R3-R6 strategies	≥ 60% of collected units reintegrated through the circular strategies (R3-R6)
Stakeholder Participation Index	Collaboration and communication monitoring	Qualitative assessment via interviews and surveys	High engagement score in annual reviews
Trained Installers Metric	Enhance the local capacity of certified technicians	Number of technicians trained and certified	50+ certified technicians within 2 years

Figur 6.15. KPIs for the take-back system (Own figure)

The first KPI has as objective the stable and extensive return of used and discarded heat pumps in the take-back system, in order to ensure the supply in the system. The measurement method for this KPI is a percentage of discarded heat pumps that are returned in relation to the ones that are put on the market. The target for this KPI is equal or above 80% of return rate in 5 years. The indicator "Circular Reintegration Rate"has as objective to maximize the circular strategies implementation, such as the Reuse, Repair, Refurbish and Remanufacture. The percentage of the collected units that are redirected to the use from R3 to R6 strategies can be used as the measurement method of the specific KPI. The target of this indicator sets a percentage of 60% and above as a limit of the collected units which will be integrated through the circular strategies R3 to R6.

The other two indicators refer to the stakeholders, one for the stakeholder participation and one for the installers. The first one is called Stakeholder Participation Index and it will monitor the collaboration and the communication between the stakeholders, by measuring via interviews and surveys, qualitative data. The target of this indicator is the high engagement of the stakeholders in the take-back system in an annual rate. The second indicator refers to the trained technicians and installers that take part in the system and has as objective to boost the local capacity of professional that hace expertise in the heat pump technology. The measurement method takes into consideration the number of technicians that are trained and certified in the span of a predetermined time period. A target for the heat pump take-back system could be at least 50 trained local installers in two years period.

The implementation of these KPIs will facilitate the monitoring and evaluation of the take-back system. Also, it can support continuous improvement over time, while analyzing KPI trends can reveal insights into system performance, stakeholder engagement, and areas requiring strategic adjustments. As the system matures, integrating advanced data analytics and feedback mechanisms can further enhance decision-making and operational efficiency.

In conclusion of Chapter 6, implementing a take-back system for heat pumps in Bornholm represents a critical step toward achieving the island's Vision 2032 and transitioning to a circular economy. Addressing regulatory, environmental, economic, and stakeholder demands is essential to ensure its success. By incorporating 9R strategies, particularly reuse, repair, and recycling, the system can maximize resource efficiency while minimizing waste. The present take-back system with a future take-back system model can differ, mostly because of the lack of circular strategies and practices in the sector of waste management. Collaboration among stakeholders, including BOFA, installers and regulatory bodies, along with pilot programs and educational initiatives, can address existing barriers and refine the system. This effort positions Bornholm as a leader in sustainable waste management and enhances its role as a model for circular economy practices in Europe.

Discussion

This chapter reflects on the design process, stakeholder involvement, and contextual challenges in developing a circular take-back system for heat pumps. Drawing on the principles of design-based research, the discussion connects theoretical frameworks with real-world constraints, emphasizing how circular economy strategies can be effectively implemented in small-scale, community-driven environments. By examining both the opportunities and limitations encountered throughout the project, particularly in the case of Bornholm and its potential replication in a Greek island context, the chapter provides a critical evaluation of the system's feasibility, scalability, and contribution to broader circular economy goals. This chapter answers to the third question of the problem definition, which is *What is the contribution of the potential final circular design solution for heat pumps in Bornholm and how can it be set as an example for others?*.

7.1 Limitations

Through the process of applying the design-based research method, several limitations have emerged from the procedure of researching and implementing the theoretical framework of this project. The limitations that were presented in the process are described in the following passage, and they are highlighted in concern of context, time availability, and several exogenous barriers.

The project encountered limitations in methodology, particularly related to the use of design-based research. This approach, while valuable for developing real-world solutions to practical problems, presents challenges such as time constraints, limited access to reliable data, and complexities in designing the proposed system. The method relies on iterative cycles of design, testing, and refinement in the process of co-designing between the stakeholders, in which the time constraint of the project does not allow for many cycles of testing, limiting the maturity of the design solution and insights.

The method of design-based research is conducted in real-world settings, a fact that although it is helpful for the solution to be adaptable to a problem that already exists, it lacks the controlled environment of a research. From this method, external variables can be introduced, that can result in insufficient data analysis.

The process of collecting input from stakeholders revealed several additional obstacles that affected the development and assessment of the take-back system. One key issue was the limited availability of certain stakeholders, particularly those from the private sector and national regulatory bodies. The scheduling of interviews and the securing of participation proved challenging, although there was at least one interview that expanded the perspective and knowledge of the main stakeholders. Despite efforts to reach a wider group of manufacturers, the small sample size limits the generalizability of the findings. The perspectives gathered may not fully capture the diversity of approaches, challenges, and strategies across the entire heat pump manufacturing landscape, particularly for smaller companies or those with different business models. Consequently, the conclusions drawn regarding industry readiness, support for take-back systems, and circular economy alignment should be interpreted as indicative rather than definitive.

Moreover, language barriers limited the flow of information in relation to the research of information about the island of Bornholm and the policy references for it. This led to a need for repeated clarification, both from interviewees and from online sources, while in some cases it limited the richness of qualitative insights.

Implementing circular economy strategies, particularly the 9R framework, which emphasizes reducing resource consumption and maintaining the flow of materials, requires substantial infrastructure investment and a change in societal behavior, both of which are time and financially consuming. In developing a heat pump take-back system, both cost and quantifiable environmental gain require careful consideration. Likewise, existing policies and regulations around heat pump disposal and recycling are restricted and do not allow trials of innovative, small-scale circular economy schemes in local contexts, such as the island of Bornholm.

These limitations highlight the complexity of designing a circular take-back model in a real-world context, especially in a geographically and administratively distinct region like Bornholm. They underscore the importance of treating this thesis as an exploratory step towards a solution that can contribute to the transition and the creation of a system that is based in circular principles.

The success of a heat pump take-back system in a small-scale community such as Bornholm depends greatly on the time and funding of the project. While the concept aligns well with the principles of the circular economy and the EU's regulatory direction, its practical implementation is a long-term planning project. Establishing a fully functional take-back infrastructure can take several years in planning for stakeholder coordination to logistics and material recovery, especially because this system does not exist in the area yet. A significant amount of funds is also a requirement for a project like this, not only in physical infrastructure but also in administrative capacity and stakeholder training. Equally critical is the implementation of the higher circularity strategies and the harmonization with the eco-design directives for heat pumps from the manufacturers, in order to allow easier disassembly. Without these design adaptations, the cost-effectiveness and environmental values of a take-back system diminish considerably. Therefore, while a successful system is feasible, it requires a phased approach supported by stable funding, policy alignment, and strong collaboration between manufacturers, local authorities, recyclers, and end-users. Short-term gains may be limited, but with sustained effort and design integration, a meaningful impact could be seen within a 5- to 10-year horizon.

7.2 Adapting the take-back system for heat pumps to a Greek island

As part of the creation and design of the take-back system for heat pumps, the focus was on the island of Bornholm, due to its sustainability goals, its pioneer position in the circular economy and the small-scale community that can help test systems in their early stages. A valuable extension of this pilot model system is the evaluation in relation to the scalability and transferability of it under similar conditions. A first face value dive into a Greek island that has set the same goals in adopting circular economy principles provides an opportunity to assess how adaptable this system can be across geographic, institutional, and cultural settings. The island of Kythnos is a Cycladic island with a population of approximately 1.456 residents, and is pioneering in sustainability through its 'Kythnos Smart Island' initiative (Komninos K. , 2024). Through this project, which integrates renewable energy, smart infrastructure, and circular economy principles to transform the island into a model for sustainable development, Kythnos also focuses on waste management on the island (Komninos K. , 2024). A key effort is being the creation of a model area of sorting and managing bulky waste, which includes electrical and electronic waste (DAFNI, 2022). The WEEE on the island is approximately 8 tonnes yearly, and the existing plan describes the collection of them in a predefined area that is included in the Model Center for the Management of Bulky and Green Waste (Komninos K. , 2024).

Although the plan is focusing in many different sectors, the take-back system for heat pumps can spark an interest for the island, since they already manage recyclable wastes in the local recycling center. By upgrading public infrastructure and fostering community engagement, Kythnos can aim to enhance resource efficiency and reduce environmental impact from the landfill (Komninos K. , 2024).

Unchanged characteristics of the system
In the context of adapting the system to the Greek conditions, there are several elements that can be applied directly.

Firstly, the classification of actors on Kythnos can be mapped out with the same criteria as it was done in Bornholm, and the role of stakeholders involved in the process of implementing the circular strategies can be transferred to the conditions of the island. In Kythnos island operates a Recyclable Materials Transfer Station, which is under a private company that manages the wastes on landfill (DAFNI, 2022). Although its existence, the island does not have access to facilities of advanced waste management, especially for electronic and electrical equipment like heat pumps that have an intricate managing system (Komninos K. , 2024). Otherwise, the mapping of stakeholders is the same procedure as in Bornholm, because of the need of participating stakeholders from municipal, regulatory, technical, manufacturing, and local level. The island of Kythnos has also developed a pilot program for recyclable waste on the island, that could facilitate the take-back system.

As far as the circular economy principles are concerned, the 9R strategies are universally applicable and their adaptability does not depend on the geographical position. The main strategies, Repair, Reuse and Recycle apply in the same way in Kythnos as they are in Bornholm, which are the core of the take-back system for heat pumps.

Additionally, the method used for the co-designing of the take-back system among the stakeholders can be easily applied as it is in the context of Kythnos, as long as the procedure follows the iterative approach of the method, in order to refine the system through stakeholder feedback and real-world constraints.

Modifications of the system
The Greek climate conditions differ from the Danish conditions, which means that the heating and cooling systems are based on different technologies and equipment. However, in the Greek market, there is a high consumption of residential air-to-air heat pumps (air conditioners) used for cooling, especially in the islands, and most of them are used in touristic regions (European Commission,

2024*c*). The differentiation in the type of equipment that the take-back system would focus on is a modification for the system, in order to adapt to the Greek circumstances. Tourism pressure should also be taken into account in the modification of the system, because seasonal population changes can lead to different logistics (European Commission, 2024*c*).

Another modification could be the public awareness and participation of the people of the two different islands. In comparison of the two communities, the Danish community is more familiar with circular initiatives than the Greek community, so emphasis should be placed on education campaigns and community-driven initiatives. In Kythnos, there is already an initiative through the program of 'Kythnos Smart Island' that raises awareness about waste management.

Added value of comparative piloting
The testing of the model in a different environment can have several benefits in the implementation of circular strategies in the model developed for Bornholm. Differences in climate, infrastructure, and socioeconomic dynamics allow a deeper understanding of how adaptable and innovative such a system truly is.

Testing the applicability in a different environment for a system that involves stakeholders from private sectors and a business perspective, enhances the economic argument for manufacturers, retailers, and investors. It shows that circularity is not only applicable in high-resource environments such as Denmark, but can also thrive in more decentralized, resource-constrained settings (Pichlmeier F., 2024).

In addition, the application of the model on a Kythnos, which faces challenges related to tourism and underdeveloped waste infrastructure. Setting the developed system in alternate conditions demonstrates the structural resilience of circular models when they are put in practice (Pichlmeier F., 2024).

Furthermore, Bornholm's vision of zero waste and participation in the European innovation landscape describes it as a model for other islands to follow its practices and planning policy, adapted to their capabilities (Christensen, D. A. M., et al. , 2021). The dual setup for a take-back system can generate more empirical data for the consumer behavior and institutional support, especially if the focus market is restricted to the European market of heat pumps and the stakeholders who participate are interested in both countries. This comparative insight can be particularly useful to policymakers who search for recommendations based on empirical data to support broader circular economy initiatives, such as the EU's Green Deal and Critical Raw Materials Act.

The information about the island of Kythnos and the planning system resulted from an extensive online research, navigating through online articles and statements from the participants of the project. As for the applicability of this project in a Greek island, that carries the same characteristics of Kythnos and participates to circular initiatives, the potential of success can be the same. This happens due to the geographical proximity of most islands in Greece, which helps the municipal and local authorities to cooperate in different circumstances and share facilities and resources.

7.3 Bottom up approach

In the context of this thesis, the inclusion of the bottom-up planning approach is critical to understanding how circular strategies, and in particular the proposed take-back system, can be effectively implemented within small-scale communities like Bornholm. As this project demonstrates, technical and policy solutions alone are insufficient without active participation and empowerment of local stakeholders. The bottom up approach reinforces the importance of community ownership in shaping sustainable transitions, enabling more context-specific, socially grounded, and resilient outcomes. By involving local actors such as BOFA, installers, end-users, and educational institutions in the co-design and operation of the system, the initiative moves beyond top down directives and instead becomes a participatory process that aligns with local capacities, needs, and values. This is especially relevant for practices like repair and reuse, which depend heavily on localized knowledge and engagement. Including the bottom-up dimension in the discussion not only strengthens the socio-technical foundation of the take-back system, but also positions Bornholm as a replicable model for community-driven circular innovation.

The bottom up approach in development and planning is an approach which focuses on how a community can take charge of their future in their area. It gives the opportunity to local stakeholders to participate in the decision-making process and to tackle real-world challenges facing their own community or to implement strategies adaptable to their own conditions (European Commission, 1999). The bottom up approach is not a regulation that must be followed or a plan ready to be applied in every community, since it is a desirable working approach (European Commission, 1999). In the area that a bottom up approach has been developed, the results of it are expected to be multidimensional and in coherence with the problem at hand (European Commission, 1999).

Furthermore, in the academic literature, the combination of the circular economy framework and the bottom up approach has draw the attention for researchers, due to the gap in implementing effective circular economy practices in small-scale communities. The developed framework of Design-led repair & reuse (DLRR) (D'Urzo M. & Campagnaro C., 2023), proposes a framework of circular practices that strengthen the social dimension of the circular economy and focus on small-scale communities with actors who are interested in the environmental dimension of circularity and are not driven only by the business perspective (D'Urzo M. & Campagnaro C., 2023). The focus of the DLRR framework is the empowerment of local stakeholders in the design process of a circular plan and the decision making on it at the local level (D'Urzo M. & Campagnaro C., 2023). Attention is paid to clear communication and consideration of local actors, in order to highlight the challenges and barriers the community must face (D'Urzo M. & Campagnaro C., 2023).

This framework ensures that local actors would be taken into account in the progress of decision-making, while starting from a small community can lead to the adoption of circular technical and social practices that are suitable for sustainable development (D'Urzo M. & Campagnaro C., 2023). An example of this is the implementation of circular practices, such as Repair and Reuse, which promote a greater participation of people and experts, compared to automated practices, such as Recycling. The inclination of choosing automated practices is promoting a top down approach, which does not include the local technicians and workforce of a small community in establishing facilities or programs for repair and reuse.

The social perspective of circular economy practices is important in the transition to circular economy, although it is not common when implementing the circular practices to focus on it, but rather on the technical aspect. The dominant circular economy narratives are also growth-oriented, and emphasize in the economic and environmental goals, neglecting the social dimensions of the problem. There is a potential in small communities to contribute to the transition, engaging them in circular initiatives (Purvis, B., et al. , 2025).

The combination of community initiatives and circular practices, in the case of Sheffield, UK, the repair strategy was mobilized, it can be fruitful for the society to promote an equitable environment within these communities (Purvis, B., et al. , 2025). These examples can empower change in the case of the take-back system in Bornholm, by providing opportunities for participation and employment in repair and repurpose activities.

Following a bottom up planning approach can also have its drawbacks in relation to funding and technical expertise. Although, choosing Bornholm as a model island for circularity and the implementation of a take-back system is based on the islands participation in this approach. Bornholm's vision in combination with its progressive municipal actors enhances the bottom up adoption in their way of planning.

7.4 Material Bank in Bornholm

To strengthen the circular foundation of the proposed heat pump take-back system, it is important to explore existing local initiatives that share similar goals and operational characteristics. BOFA's material bank for construction waste presents a valuable point of synergy, offering insights into stakeholder engagement, logistics, and circular material flows already in development in Bornholm.[1] Including this example in the discussion highlights how aligning parallel initiatives can reinforce systemic circularity, enhance resource efficiency, and support the scalability of community-led solutions.

From several initiatives of BOFA's team, the one initiative that can be explored in terms of synergy with the heat pump take-back system is the material bank for building and construction waste. While the targeted materials are different, the aim of extending the life of the products and materials, while reducing the environmental impacts of virgin materials is the same in both cases.

There is common ground in both BOFA initiative systems, as both rely on collecting, sorting, and documenting the materials and products. The logistical plan for the Bornholm material bank mirrors the logistic needs in the heat pump take-back system, so there is an opportunity to share physical infrastructure. A next step for investigation for the two systems could be a shared digital infrastructure, such as a database for materials and components, and the way in which it can support both systems efficiently.

The material bank is a vision developed for the Living Lab of Bornholm in order to facilitate a 'give-and-take' system for construction and building materials, in which there is emphasis in

[1]The project of material bank is an ongoing project for Bornholm, reformulated by the authors Christensen, T. B., Johansen, M. R., Buchard, M. V., & Glarborg, C. N. (2022). Closing the material loops for construction and demolition waste: The circular economy on the island Bornholm, Denmark. Resources, Conservation & Recycling Advances, 15, 200104.

stakeholder engagement, iterative design, and experimentation on the system, characteristics that are similar to the take-back system for the heat pumps. The common purpose of these two models to manage the waste streams can build a strong circular culture in the island and can also facilitate cross-learning in stakeholder collaboration methods, broader citizen participation and join pilots on selective demolition and equipment removal. An example of this would be the reclaiming of a building on the island that already has an integrated heat pump system.

In addition, the existing culture on the island of exchange practices between self-builders, to salvage bricks or windows, could be extended among actors in the heat pump sector. The citizens who are familiar with refurbished products and are open to the community-led reuse hubs, may express interest to similar models, such as owning a refurbished heat pump.

Furthermore, the two systems align with the national and EU circular economy goals for reducing landfill and increasing resource recovery. Although, the policy framework of return material systems does not covers several points for certain products and procedures, such as the handling of heat pumps from only people with certification of electrician or technician. A coordinated policy framework could amplify the benefits of these systems and position Bornholm as a testbed for multi-sectoral circular policy.

In summary, aligning the material bank initiative with the heat pump take-back system model offers considerable advantages for the implementation of circular practices in Bornholm, in terms of infrastructure, stakeholder engagement, behavioral reinforcement, and environmental performance. A synergy between the two pilot projects could serve as foundation for a replicable circular system model for other small island communities.

7.5 Life Cycle Assessment (LCA)

Life Cycle Assessment (LCA) is used frequently, when contemplating decision making, in multiple product or system cases for electronic and electrical equipment. In the form of a system to assess a take-back system for heat pumps, LCA is useful in that LCA will give an overall view of the environmental impacts of the heat pump take-back system, it will view the take-back system's environmental impacts across the full life cycle, from raw materials extraction and manufacturing, through transportation, use, disposal, and recycling (Greening, B. and Azapagic, A., 2012).

This type of methodology will allow a project to quantify an environmental performance value for each phase of the life of a heat pump, one can consider the disposal mechanisms available and the environmental benefits of a take-back versus disposal route. In such an analysis, one could find findings that could be focused on as areas for wholesale reduction in carbon emissions, energy use, and material waste, in encouragement to more sustainable decision-making.

Even while this mapping and quantification dimension has significant merit, applying the principals of LCA to a heat pump take-back system will also have several challenges. The first of such challenges is the need for data with attributed accuracy and completeness. The heat pump market is a complicated market - it has different materials, manufacturing technology, and stakeholders in the employment chain. Moreover, there can be gaps in data to differentiate the life cycle of the heat pump, particularly when the heat pump reaches the disposal stage and the unit must be disassembled and recycled. In such cases the data uncertainty could be dramatic enough to potentially limit the usefulness of an analysis (Ismail, H. and Hanafiah, M. M., 2019).

Additionally, while LCA can highlight many environmental impacts of a take-back system, it cannot fully account for the social and economic aspects, like consumer behaviours, cost considerations, and whether or not a practical take-back system could be employed. For instance, an analysis could identify a range of environmental benefits, but still, possess offsetting costs, practical limitations, and lower public participation. Any limitations could reduce the overall impact of the system, even if an analysis concludes the environmental benefits of a take-back system are favorable(Ismail, H. and Hanafiah, M. M., 2019).

Subsequently, LCA can advance knowledge of environmental impacts of a take-back system, but LCA results should not stand alone. To build a more holistic understanding of a take-back system, more consideration is required when bringing perspectives from stakeholders, along with the practicalities of each, when exploring a collaborative system.

Overall, LCA may be a methodical framework to environmental appraise a heat pump take-back system, while providing valuable data to support an informed decision of environmental benefits of a take-back system for Ontario via conceptualized basis. At the same time, due to LCA relying on data availability and being geared towards environmental impacts from a perspective, there will be an operational side to the evaluation that must rely on some collective approaches with stakeholder engagement and economic analysis. Providing an understanding of whether a take-back system is not only environmentally best, but best suited to develop a practical feasibility of implementation.

Concluding the Chapter 7, it has examined the complex considerations of tabletop designing and practical implementation of a circular take-back system, focusing on Bornholm and potential adaptation to other small island contexts, such as the islands of Greece. Design-based research has established the validity of stakeholder collaboration, "real-world"testing, and ongoing co-design in developing circular solutions. Despite constraints related to time, data, and engagement with stakeholders, the research has established a baseline of understanding about the operational, social, and regulatory complexities associated with circular economy design processes.

The analysis highlights that a viable take-back system must incorporate more than just technical planning and built infrastructure. It must also be predicated on a strong bottom-up building block that is rooted in community/consumer engagement and stakeholder empowerment. Where synergies with existing initiatives, such as Bornholm's material bank, highlight integrated system examples that can bolster circular practices across sectors. In addition, the comparative analysis of opportunities for transferring the model to a Greek island illustrated that circular principles can be applied contextually and flexibly.

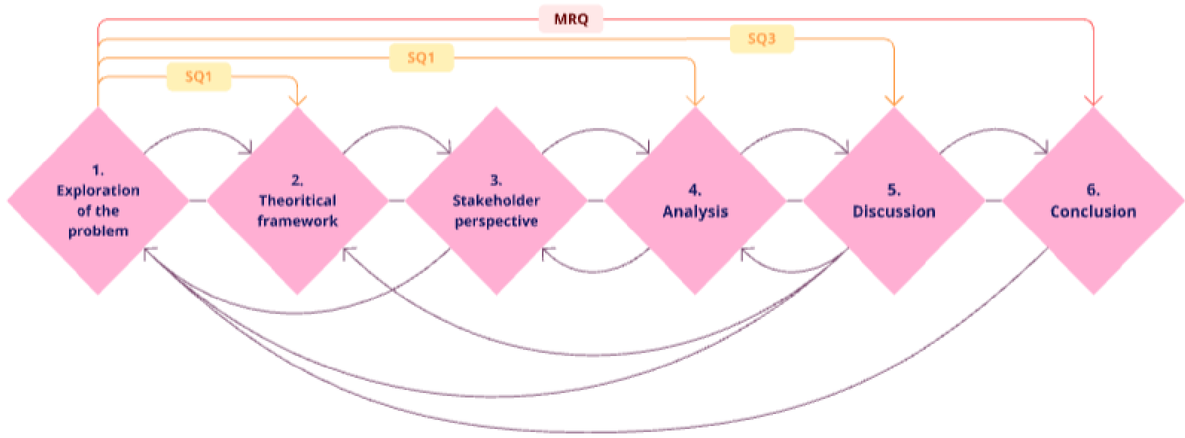
Finally, while tools based (like LCA) are useful in providing important contexts, the analysis demonstrates the need for whole evaluation, including economic and social dynamics, and sustainability implications of design. As such, this project should be considered an exploratory first step towards a more robust, broader circular system, focused on collaboration, policy, and growth-oriented sustainability.

Conclusion

The transition toward a circular economy is no longer an abstract ambition, but an urgent necessity, especially in the context of rapidly growing electrical and electronic equipment waste. As highlighted throughout this project, the management of heat pumps throughout their life cycle, although recognized as a key technology in achieving Europe's decarbonization goals, remains largely aligned with a linear economic model. This model, characterized by 'take-make-dispose' practices, undermines environmental sustainability and contradicts the foundational principles of circularity.

Through the case of Bornholm, this thesis has illustrated that, while there is clear momentum in circular initiatives and a strong sustainability agenda, a crucial gap persists: the lack of a systematic and circular end-of-life strategy for heat pumps. The research identifies the implementation of a return system as a central recommendation, a concrete and actionable mechanism to shift the life cycle of heat pumps into a circular framework.

The application of the design-based research (DBR) methodology in this project yielded valuable qualitative insights. However, it also encountered limitations, including time constraints, restricted access to data, and the inherent complexity of designing a practical, real-world solution. The final representation of the DBR methodology's iterative process in this project is illustrated in Figure 8.1. In particular, several iterations occurred between the problem exploration and the analytical phase of the project, while the feedback from the different stakeholders' interviews created their own iterations between the analysis, the theories and the problem definition. The recommendations that are presented in the analysis created as part of the iterations, while implementing the theoretical framework. Furthermore, the discussion and conclusion stages prompted a return to the initial definition of the problem and the theoretical framework, highlighting the need for continuous validation through the literature and reinforcing the iterative nature of the DBR approach.



Figur 8.1. The visualization of the DBR method applied in this project (Own figure)

The answer to the main question *"How can the co-design of a take-back system in Bornholm from stakeholders in the heat pump sector be an innovative strategy for the transition to circular economy by implementing the 9R circular strategies?"* is answered, after the consideration of the theoretical framework, the analysis, and the discussion.

The take-back system as a strategic solution
The advanced take-back system proposed in this thesis acts as both an infrastructural and organizational solution. It is designed to collect, assess, and process discarded heat pumps, allowing their components to be repaired, refurbished, reused, remanufactured, or recycled, in alignment with 9R strategies. In doing so, it directly contributes to reducing waste generation, conserving valuable materials such as copper, aluminum, and rare earth elements, and decreasing the dependency on virgin raw materials, especially those classified as Critical Raw Materials (CRM).

Moreover, the take-back system addresses a range of systematic issues that can be crucial for the transition to a circular economy. This system bridges the policy of heat pumps and circularity principles to practice by taking into consideration regulations like Eco-design in the process of co-creating a system by all stakeholders. The stakeholder engagement can also be enhanced by distributing a role to actors that were not participating like BEOF, and redistribute responsibility to already involved stakeholders who are passive in action, like the manufacturers. A system of many stakeholders that focuses on implementing circular strategies creates economic value in the supply chain by stimulating different models (e.g., services like repair) and secondary material markets. In this way, the advanced take-back system is not only a technical solution but also a catalyst for circular transformation.

Additionally, the integration of the 9R strategies has proven essential in framing the project's circular objectives. By analyzing heat pump management through the array of strategies and mapping out which of them are in practice from the stakeholders, this project has identified that higher-value strategies, such as reuse, repair, and remanufacture, must be prioritized. Although the highest circular strategies, Refuse, Rethink and Reduce, must be integrated into the design process of the manufacturing and production process. On the other hand, lower value strategies like Recycle should serve only as last resort options, especially on the occasions that are considered downcycling, like BOFA highlights for their process.

The take-back system activates this hierarchy by creating feedback loops between stakeholders, allowing product evaluation, material classification, and component classification. This supports the system in maintaining resource integrity at the highest possible level and minimizes downcycling. By implementing this framework, the project moves beyond recycling and toward a more regenerative and restorative circular model.

Eco-design as critical lever
Although end-of-life solutions are vital, circularity must begin in the design phase. The principles of eco-design are central to the design of heat pumps with durability, modularity, and easy to disassemble. Regulations like the Eco-design for Sustainable Products Regulation (ESPR) are beginning to mandate such practices, but their integration in real-world products is still in its first steps.

There is great potential for manufacturers and producers to integrate the principles of Eco-design in their company's agenda, since the future commands it. One of the designs that they could follow and create values for take-back systems is the Design for Disassembly (DfD) principles in order to simplify the process of material recovery. Furthermore, the principle of modularity in the technology of heat pumps is of great importance, since heat pumps have many different components that they consist of. Modular design approaches can facilitate the repair and reuse of these components by the producing companies.

For circular transitions to be successful both as a technological and business innovation, they require supportive policy environments. There is complexity in EU regulations and directives for their implementation, since they can create barriers and hinder progress. A shift in policy decisions can begin with some of the recommendations of key policies, such as a mandatory take-back obligatory framework that can extend to manufacturers and retailers. The economic incentives of policy can also lead the transition by creating rewards or penalties tied to circular performance indicators, or funding repair and reuse initiatives, that includes training programs for the installers and certification programs for refurbishment centers. In addition, the expansion of the Extended Producer Responsibility (EPR) framework can ensure that the burden of waste is shifted upstream, incentivizing better product design and circular business models.

Small-scale community adaptation
Finally, one of the most important findings is the suitability and replicability of this take-back model in small-scale communities, particularly those with restricted or semi-autonomous systems such as islands. Bornholm presents a valuable testbed for its size, infrastructure, and community engagement, that make it an ideal case for piloting circular systems. The communities on islands can leverage closer stakeholder engagement that leads to faster implementation of practices and direct feedback, while the alignment of economic and environmental goals can help create local opportunities for workshops and positions in collection, maintenance, and refurbishment of a system. In addition, the participatory and community-focused nature of such systems improves public acceptance and behavioral change, crucial components of any circular initiative.

This model can be transferred to other European islands, remote towns, or municipalities that are pursuing sustainable development goals but lack complex waste treatment infrastructure.

Economic and educational benefits

Beyond its environmental and systemic advantages, the implementation of an advanced take-back system holds considerable potential for local economic development on Bornholm. The creation of such a system would likely result in new employment opportunities, with a small, dedicated team of two to three individuals needed to manage and operate the logistical, technical, and administrative aspects of the system. These roles would support ongoing coordination between stakeholders, oversee the recovery and refurbishment processes, and ensure compliance with circularity metrics and reporting. This initiative can contribute to the development of green jobs on the island and help diversify its local labor market in alignment with Bornholm's broader sustainability goals.

Additionally, the take-back system could serve as a platform for academic collaboration and knowledge transfer. Through partnerships with universities and vocational institutions, it is expected that between five to ten student internships or graduation projects could be hosted annually, spanning fields such as circular economy, industrial ecology, product design, and energy systems. These collaborations would not only support the system's continuous improvement through research and innovation but also foster a culture of learning and experimentation around sustainable technologies. In this way, the system can simultaneously address practical circularity challenges and act as a catalyst for education, capacity building, and long-term community engagement.

In conclusion, this project positions the take-back system as an essential and scalable strategy to align the heat pump sector with the goals of the circular economy. It has the potential to transform waste into a resource, to enable new forms of stakeholder collaboration, and to change social norms around the use and disposal of products.

Bornholm, with its ambition of becoming a zero-waste island by 2032, is not only an ideal context for piloting such a system, but it can serve as an inspirational model for other communities. By embedding circularity into both practice and policy, this approach demonstrates that the circular economy is not only viable, it is imperative. However, further investigation is needed for the system to operate, mainly a pilot for the island to gather data and identify potential challenges for the future. Future research would benefit from engaging a broader set of stakeholders to strengthen the representativeness and depth of the analysis.

Ultimately, the future of sustainable heating lies in integrated systems where products are circular in design, recovery is systemic, and value is preserved throughout the life cycle. The take-back system for heat pumps is one such path forward, one that combines innovation, regulation, and cooperation to realize the promise of a truly circular society.

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Appendix

9.1 Appendix 1

Interview with David Christensen and Anine Selander from BOFA

The main aim of this project is to conduct interviews with various stakeholders to evaluate the potential feasibility of implementing a take-back system for heat pumps. The insights gathered from these interviews are intended to inform whether such a system could be viable and effective. The questions posed are designed to explore stakeholders' perspectives and identify possible actions that could support the transition from a linear to a circular economy.

Question 1. After implementing a system for recycling and repairing discarded refrigerators and freezers, what benefits do you believe have emerged from it? These can include environmental, economic, or social impacts.

The project in question, 'REuseLAB Bornholm'—also known as C7.5 under the Integrated LIFE project Circular Economy Beyond Waste—recently submitted an interim report to the project coordinators at the Central Denmark Region.

Question 2. What advantages or challenges do you foresee in implementing a similar take-back system specifically for heat pumps?

White goods are relatively easier for BOFA to collect, repair, or refurbish - particularly through third-party partnerships - and reintegrate into the system. In contrast, heat pumps present more complexity, as they are part of fixed heavy-current installations that involve indoor and outdoor units. Handling these systems requires certification as an electrician or electrical installer, which excludes vocational school students and limits the potential for involving social enterprises such as those envisioned in project C7.5.

However, implementing a similar take-back system for heat pumps would represent a significant step forward. It could provide a highly circular solution for managing another growing e-waste stream.

Question 3. Do you think a system similar to the one you already have could be adapted or further developed to include heat pumps, despite their added complexity?

Absolutely, but with some concerns.

Question 4. What financial or logistical barriers do you foresee that might hinder the implementation of a take-back system for heat pumps?

Given that heat pumps are less common than white goods such as refrigerators and freezers, how do you see the issue of quantity affecting the feasibility of a take-back scheme, whether run as a social enterprise or for-profit model? Specifically, do you think the volume of returned units would be sufficient to cover a significant portion of the system's operational costs through resale or reuse?

Additionally, considering that only certified electricians or electrical installers are permitted to dismantle heat pump systems for safety reasons, what are your thoughts on this technical bottleneck? How might it impact the logistics and stakeholder involvement necessary for such a system to function effectively?

Question 5. What role do you envision BOFA playing in the design, development, and implementation of a take-back and refurbishment system for heat pumps? How could BOFA's existing infrastructure, expertise, or partnerships be leveraged to support such a system?

BOFA currently receives e-waste through its collection points and is interested in promoting more sustainable, circular approaches to managing this waste stream. BOFA could potentially act as a facilitator or project owner in testing a take-back and refurbishment system for heat pumps, collaborating with the right stakeholders.

However, a significant challenge is that e-waste in Denmark is managed under Extended Producer Responsibility (EPR) schemes. Once e-waste is deposited at BOFA's facilities and officially classified as waste, the EPR organizations claim ownership and strictly control its handling. These organizations primarily focus on downstream, outer-circle circular strategies such as material recovery and recycling, with limited emphasis on inner-circle strategies like product lifetime extension.

Additionally, from BOFA's perspective, waste processed through the EPR recycling system counts as 100% recycled, which aligns well with BOFA's Vision 2032 goals centered around zero waste, mainly defined as phasing out landfilling and incineration. Because current metrics already recognize e-waste recycling at this level, some within BOFA's management prioritize these outcomes over inner-circle strategies, which are harder to measure within existing monitoring frameworks.

Question 6. What type of help from manufacturers or government authorities would be essential to ensure the success and feasibility of such a system?

Extended Producer Responsibility (EPR) organizations managing e-waste would ideally need to support this initiative, although it might conflict with producers' interests in promoting the sale of newer, more energy-efficient heat pump models. Funding to cover the costs of circular take-back programs, including labor for all parties involved, would be crucial. Furthermore, government incentives, such as tax breaks or subsidies for end-users participating in the system, would greatly enhance its viability.

Question 7. Are there additional stakeholders you believe could partner with you in creating a take-back system for heat pumps?

Since only certified electricians or electrical installers are authorized to handle heat pump systems, involving these SMEs would be essential. On the municipal side, besides BOFA, there are likely 2-3 other municipal departments that should be engaged, such as the facilities management unit responsible for municipal buildings, the environmental department overseeing SMEs and industry, and the municipality's energy development unit, which is currently under-resourced. Additionally, Campus Bornholm, where vocational training for electricians takes place, would be a key stakeholder to include.

Question 8. Are there any initiatives or measures aimed at encouraging consumers on Bornholm to recycle old appliances such as refrigerators or heat pumps?

No, not that I'm aware of. BOFA provides a service where residents and businesses can drop off their e-waste for recycling, but there isn't an active campaign encouraging people to discard old devices. There used to be an energy advisory service called "EnergiTjenesten" on Bornholm that played a key role in this area, but it was discontinued in December 2018.

Question 9. How do you see BOFA's role in advancing circular economy initiatives, including product take-back systems and recycling efforts?

BOFA should take on a leading facilitator role in line with Vision 2032, while carefully considering who is responsible for carrying out core functions in product take-back systems and how these are financed. If producers are responsible, they should also fund these initiatives. As a municipal waste management entity, we must be cautious with the way we allocate waste fees to citizens and businesses to avoid exceeding our legal mandate and operational scope. However, we are open to experimentation and funding through projects such as the EU-supported C7.5 REuseLAB Bornholm would be a valuable opportunity to pilot such initiatives.

Question 10. What is your opinion on introducing a take-back system specifically for heat pumps?

If we're talking about end-of-life management, BOFA already handles the collection service for EPR organizations through our recycling centers, which then manage the downstream logistics. However, if the focus is on extending product life, through take-back, repair, refurbishment, and recirculation to the same or new users, that would be an excellent initiative. For that to work, we'd need to develop appropriate metrics to align with our Vision 2032 waste treatment tracking, involve the right partners with suitable (possibly social enterprise) business models, and address logistics and financing. Overall, this approach would be highly beneficial. From an LCA standpoint, extending the lifespan of products is generally more favorable, even when newer products are more energy efficient.

Question 11. Are you currently equipped to manage a take-back system in terms of collection sites, transportation, staffing, storage, and infrastructure?

No, not fully. While we do have established collection points and personnel overseeing them—despite being stretched thin—and some available storage capacity, we would still require external partners to support most of the necessary functions for operating a take-back system effectively.

9.2 Appendix 2

Interview with installer Marcus Hansen from Flemming Svendsen VVS

The main aim of this project is to conduct interviews with various stakeholders to evaluate the potential feasibility of implementing a take-back system for heat pumps. The insights gathered from these interviews are intended to inform whether such a system could be viable and effective. The questions posed are designed to explore stakeholders' perspectives and identify possible actions that could support the transition from a linear to a circular economy.

Question 1: What issues do you currently encounter with disposing of heat pumps?

At the moment, we're not experiencing any real problems. Collections are happening regularly each week. It's been this way for the past 3–4 months.

Question 2: What is your usual process for dealing with old or broken heat pumps when replacing them with new ones?

We have an arrangement with a local recycling provider who collects them from us.

Question 3: Are you familiar with take-back programs for other products? What are your thoughts on having one specifically for heat pumps?

We already make use of return systems for old circulation pumps and toilets. However, I haven't come across one specifically for heat pumps.

Question 4: Does your company currently participate in any official product return scheme for heat pumps? If not, would you be open to joining one if it became available?

We're not part of any such scheme right now, but we'd be open to the idea if it were introduced.

Question 5: In your view, how can installers help environmental efforts by engaging in a take-back initiative?

Installers could have a significant positive impact, but as of now, I'm not aware of any such efforts in place.

Question 6: What kind of logistical, storage, or transport support would make participating in a take-back system manageable for your company?

It needs to be straightforward—just knowing clearly where to drop items off would help. Ideally, someone else should handle the process, as we lack the time.

Question 7: What type of incentives—whether environmental, financial, or operational—would encourage your involvement in a take-back program?

We'd be driven more by environmental benefits than financial gain. Money isn't the main concern.

Question 8: Would your company be willing to collaborate with waste handlers or manufacturers to support a take-back system?

Absolutely, we'd be happy to cooperate.

Question 9: How might a take-back system help raise awareness among professionals and customers about proper disposal practices?

A well-organized system would make it more noticeable to us. We already have such programs with other products like pumps and toilets, where the manufacturers handle recycling.

Question 10: What role do you think your business plays in helping Bornholm reach its environmental and waste-reduction targets?

We believe we play a key part, since we're one of the island's major firms handling installations of heat pumps, ventilation systems, and similar technologies.

9.3 Appendix 3

Interview with Nadine Haxgart from A/O Johansen

Overall, the interview provided insight into how the company currently manages heat pumps and what, if any, future plans they have concerning the disposal or recycling of heat pump units.

Question 1: What is the nature of A&O's involvement with heat pumps? Do you handle sales, design, production, or repairs?

Their role is limited to the sale of heat pumps. In cases where a unit is returned, they may offer repair and resell it at a lower price, though such items are sold without a warranty.

Question 2: What internal policies does A&O have in place concerning heat pumps?

There aren't many policies in place. They generally do not accept returns and typically dispose of units that are not functional or accepted back.

Question 3: Has A&O implemented a take-back system for heat pumps?

No, such a system has not been adopted. They cited lack of space and capacity to store returned units as the main obstacle.

Question 4: Does A&O supply heat pumps for residential or commercial use?

They supply heat pumps for both residential and commercial purposes, but their customer base consists exclusively of professionals such as builders, installers, and technicians.

Question 5: Are there any current or planned initiatives at A&O for the recycling of heat pumps?

There are no recycling initiatives in place for the heat pumps themselves. Their efforts are currently focused on recycling and minimizing product packaging.

9.4 Appendix 4

Interview with Ebba Fjelkner from Alfa Laval

00:00:00 Ebba Fjelkner

As you have seen from the questions that I have send you, my thesis is focused on the heat pump sector and circularity and how the transition can be from linear to the circular economy. I am trying to find manufacturers or other big companies that participate in this sector of manufacturing heat pump or similar equipment. The aim of the interview is to understand the perspective of these manufacturers and understand their point of view. So, as you have seen from the questions, the first question is about your role in the company and what your responsibilities are.

00:00:53 Ebba Fjelkner

Yeah, absolutely. I'm working as a business engineer for HVAC, which is basically anything related to heating and cooling. And I'm specifically working with gasketed plate heat exchangers. So it's one of our product types that goes into those kinds of applications. And I am working with, what we call, the umbrella of Sustainable City, so it is everything related to energy within sustainable cities and I mainly work more with specific like building heating and those kind of applications, but heat pumps comes into that since it's so related, so it's not really our expertise, but it's within the field that I'm working with and it's still quite applicable. So I hope that I can give you some insights.

00:01:53 Paraskevi Striga

Also, I wanted to ask what is your company's position in this kind of circularity scheme and how do you perceive circularity?

00:02:09 Ebba Fjelkner

I think for me it's really divided into two different areas, and I think I understood from your questions that you're focusing more on material circularity. Because we talk a lot about energy circularity and kind of recovering heat from waste heat sources and things like that. So that's a lot of what I am focusing on. Since we are selling equipment, it's usually if you bring a heat exchanger or a heat pump into the market, it's I mean, and if ranging from 10 to 60 years of product life cycle. So of course, it's still really important that we do something good with the price when we bring them in, but it's not the same scope as more of fast-paced consumer goods.

So for us one of our sustainability pillars is circularity. We also talk a lot about circularity for water and those kinds of aspects as well because we do like filter equipment and things like that. So it's really an important point for us as well to both contain our resources and also limit greenhouse gas emissions.

00:03:31 Paraskevi Striga

Okay. So how would you describe as a manufacturer the promotion of circularity through your company, like you said the company is more focused on the part of circularity about efficiency and not so much about the material part of circularity. Are you following some strategy or some policies that focus on the implementation of circularity.

00:04:01 Ebba Fjelkner

Yes, if we talk about specifically the product group that I'm working with, we have several different programs. But for example, we're working a lot with the design of the heat exchanger. So bringing in recycled metals, for example into new products as a way to find a use case for recycling metals so that we are really working a lot with how to make that value chain work together with our suppliers. Also, in our own manufacturing, how to keep it separate and follow the material flows and product flows. So that's one part we're working very closely with. Both our main components are metal and rubber, so we're doing the same with our rubber suppliers. And then more when it comes to like end of life, we're collaborating with recycling companies. Now it's mainly Europe focused because that's where we have the collaboration, but to build a kind of program where our end customers can send in their old equipment to the recycler and get benefits for that or when buying a new product, which is kind of some creditation system for users sending in their old equipment for recycling.

00:05:40 Paraskevi Striga

So will the recycling company be the main link between your company and the consumers of your products, in the occasion of recycling the products in the end-of-their life?

00:06:11 Ebba Fjelkner

No. We are connecting the two stakeholders. I can say that we have the collaboration between our costumer and the recycling company, so we can bring the two of them together.

00:06:25 Paraskevi Striga

OK, so like when we're talking about like a take back system between different stakeholders like you, the recycling companies, the consumers and some municipal organization, like a municipality or an NGO, how do you see your role as a manufacturer or producer in a system like this?

00:07:05 Ebba Fjelkner

I mean, it's really about building the bridge the fact that the product is recyclable, it is important to give that information to the end costumer. Also, we make sure that the components we put into our heat exchanger are as sustainable and recyclable as possible, and the design of the unit itself. We are working on that to make sure that we remove for example, any substances that would be harmful within recycling and so forth. So, we have quite a strict policy when it comes to the substances that our products contain.

00:07:48 Paraskevi Striga

Do you think that a take-back system would work for your company? Except of being feasible, is it economically or environmentally worthy for your company?

00:08:10 Ebba Fjelkner

At the moment it's such a small scale still, so it's really difficult to see the actual impact and I think getting the interest of doing it is also a struggle. From a practical perspective, if you have a building site for example, by the time it gets torn down, the company responsible for is not the same as the one that we have a collaboration with and can actually impact the recycling process of the product. They might just have a huge waste bin and everything that is worthy there, like metal scrap. So, I think that can be a a struggle. Also, even if we are collaborating with a specific end customer, they might have a contractor doing the tearing down part, taking care of all the waste. But I think from a sustainability perspective, I think it's feasible and it makes sense because there is benefit to it, and especially with metal to like lessen the mining. And I mean if you can remove that part of course still the reworking of the metal still has an impact on the environment, but it is less starting from extracting the virgin materials at least.

00:09:39 Paraskevi Striga

And except for the communication struggles that may exist among stakeholders, do you find any other barriers to exist around this take back system?

00:10:01 Ebba Fjelkner

I think it's also important to have the demand for the recycled materials and that's what we're trying to create by using it as well of course. But at the moment it's more costly to recycle than to use virgin material. And if there's not a demand for it, it's really difficult to translate the cost, so that's an economical issue, of course. But I mean, in small scale it can still work but as soon as it gets into bigger scale that will become problematic.

00:10:37 Paraskevi Striga

Yes, I understand. Because for example heat pumps' life expectancy is at least for 10 years. So how do you think a take-back system is going to work in the future? Like for example in a small-scale take-back system that is implemented now in the market, the equipment that you sell now, is going to reach the end-of-life in a long time period. Do you think that this is something that affects the implementation of a system like that? Or is it something that we should see ahead and have a plan ready for the future?

00:11:33 Ebba Fjelkner

I think, as long as we can handle the ones that are already in the market, I think we can solve already now because we have, there are a lot of products. I mean there are heat pumps in a lot of homes already. So it's I think there is a possibility to start and especially to test the system with smaller numbers, which is beneficial, but for sure it will take some time before it's up and running and you really see the effect. So I think that's very true.

00:12:06 Paraskevi Striga

And also I find that the focus on the term take back system that the companies or the stakeholders thinking more about is the end of life and the how we can recycle the product and not how to implement different strategies as rethink and redesign and you talked about thinking of designing differently your products before going into the market. Do you think that between the strategy that you follow for designing your products and the circular strategies that exist is there a relation?

00:13:06 Ebba Fjelkner

Yeah, I think it's very, very relevant. And it's, I mean we need to think about what the materials we put in there. And I mean if for example, if there's a limitation in moving towards recycled content, due to whatever component we are having or that's not recyclable for example. We should think about that in the design stage, that there can be technical limitations, why it's not possible to remove and so forth, but for example I know we are looking a lot for example, metal thickness. If we can make the metal more durable, which means we can have a use of thinner metal and get the same effect, which of course is both beneficial that you need less metal, but it also weighs less and you get other positives as well. Our R&D department are looking at that in the design stage. So, yes I would say that we have the circular strategies in mind when we design and it is also probably how the design works for sure.

00:14:41 Paraskevi Striga

And what do you think about the WEEE directives? Are those directives limiting the production phase or the design phase of your products?

00:15:03 Ebba Fjelkner

I don't think we are classified as electrical equipment because we don't have any electrical components. So, to be honest, I'm not into those kind of details on the legislative steps. So I don't know exactly where we fall into. It wouldn't seem that affects us at least. We are looking a lot at the Energy Efficiency Directive, but that's more our product impacts the end users result, rather than us so much. Of course, it impacts us as well more manufacturing wise, but it's more of what our product can do to help that journey that we are looking a lot at.

00:15:42 Paraskevi Striga

OK, understandable. So if you participate in a take-back system of a bigger or smaller scale, do you think that value can be created in your company's products or the value is retained in the products that are already in the market?

00:16:09 Ebba Fjelkner

Yeah, I think it will because it helps of course the entire life cycle of it. So yes. I think we see an interest as well from our customers that it is a value add to the product to have that opportunity. In my opinion, I think that since the product has such a long lifespan, I think they're even more value to be one during its use phase, than with the take back system compared to other types of products where there are faster movement rate in their life cycle.

00:16:59 Paraskevi Striga

Can you elaborate a little bit more on that because I'm interested?

00:17:05 Ebba Fjelkner

Yes, for example, if we can have a different type of heat pumps solution. Now I think I'm not sure if you're focusing more on residential heat pumps or industrial heat pumps.

00:17:17 Paraskevi Striga

From the point of manufacture, I am focusing more on residential, but I'm valuing all of the perspectives, of course.

00:17:25 Ebba Fjelkner

Yes. Because we are looking a lot at industrial heat pumps. So you say, for example, a waste heat source that can, I mean it could be like waste water that's 15° and lifting that temperature to where you could either pre heat some type of industry or you can actually heat buildings with it or wherever, where you have the need and if you can do that on a large scale with a very efficient heat pump, you can get an coefficient of performance or efficiency of maybe 8 to10 even if you're really optimize the system. And then compare that to, for example, to an oil boiler with a 60% efficiency or in CPO a 0.6 it'a a big difference. The importance of having a more efficient systems and the energy savings and the resource savings we can do during the life of the unit, I think has a bigger value add compared to what happens at end of life.

00:18:31 Paraskevi Striga

Yes, of course. Also, a take-back system usually is based on the lower circular strategies, like recycle, repair and refurbish, does your company provide services similar to these strategies?

00:19:20 Ebba Fjelkner

Yeah, we do. I mean, we have a service organization who provides service to our units. So it's both, I mean spare parts, cleaning, different kinds of maintenance, such as checking their performance. So, with a lot of our customers, we have a very long service agreement to provide spare parts. For example, we have several customers that we have a spare parts agreement for 60 years. So, it's important for us, the customers, to choose firstly the refurbishment of the product rather than to replace it.

Then it always depends on the circumstances. For example, if we are providing spare parts, which in some cases can basically mean that you're replacing the entire units more or less then it might be that there is so much material. Sometimes the new unit could actually be more sustainable, than repairing. Over a longer period of time, it could be considered, but it's certainly something that we think is really important that we want to provide to our costumers and for the environment. Depending on what type of application the customer has, we can choose a unit that it is more serviceable and meant for that, or maybe they need something that's really small and efficient, and then maybe it's not as easy to service for repair or refurbish, but they have to choose that based on their needs.

00:21:05 Paraskevi Striga

Is this like most occasions are like for industrial equipment, not so much for residential?

00:21:15 Ebba Fjelkner

We have a lot of heating for residential as well, but I'm not specifically working with that, so that's the difference. We have some type that goes to the residential, but then it's usually some type of system in between. So for example we don't, we don't make heat pumps ourselves, but we sell heat exchangers to heat pump manufacturers. So we have that layer in between.

00:21:47 Paraskevi Striga

Can you tell me some of the barriers that you have experience in terms of circularity and implementing sustainable solutions?

00:22:21 Ebba Fjelkner

As I said, we are supplying components to someone else who are then putting them into their system and selling them to an end user. That can be a barrier when it comes to rethinking or redesigning, I think that is a layer where we don't get the feedback of what we design, what we need to make to make it easier to take back or recycle potentially. I'm not saying that it's the case, but it could be something to start off and in a communication perspective, that we are further away from the end customer. I think communication is always a struggle. But we are working with some incentives. I mean for example, if you're replacing specifically a heat exchanger and you then agree to recycle it, by using one of our recycling partners, we have an economic incentive program that you can get a discount on your new units since you are recycling the old one.

00:23:33 Paraskevi Striga

For the end user in the residential use?

00:23:41 Ebba Fjelkner

No, that would probably be more industrial use where we have a direct relationship with the customer, but it could, it could potentially work for our residential as well.

00:23:51 Paraskevi Striga

Yeah, because I think there is a service that a lot of companies, not only for heat pumps, but also for different equipment, provide an economic incentive to take back a product that is not working or it is an older model.

00:24:09 Ebba Fjelkner

Like a kickback, yes.

00:24:10 Paraskevi Striga

Yes, exactly. Also, what about the EU regulations? Do you have to follow some specific EU regulations for that, and do you feel pressure from some of these regulations as a company? Like the EPR?

00:24:42 Ebba Fjelkner

Yeah, I'm not sure specifically if there is any specific regulation that we need to consider for that kind of purpose. I mean we are focusing a lot on SDGs based on the Paris Agreement. So we want to reduce 100% in Scope 1 and 2 by 2027 and 50% by 2030 the Scope 3 and net-zero by 2050. So kind of very similar to all companies' targets and of course I mean take-back systems are to impact our end of life footprint and also including recyclable material in the design phase. It's really important step for us to make those changes because a lot of our associated greenhouse gas emissions come from materials, because we don't have such energy intensive processes as maybe other companies have. So that's for us, something that's very important in that journey and certainly we feel the pressure due to the targets that are set on companies now with the CSRCE reporting standards. You kind need to fulfill and to be a market leader and show that we are taking a stand for the climate.

00:26:42 Paraskevi Striga

In the future how do you see circular economy practices affecting the company or the role of that the company plays in the heat pump sector or in general in the heating sector?

00:27:03 Ebba Fjelkner

I think I mean, as I said with energy efficiency partly, I think we play an extremely important role in making energy efficient units that really makes a difference when it comes to circularity of energy resources that I think is very, very important.

00:27:23 Ebba Fjelkner

Basically whenever you are transferring heat or transferring energy in any way you need some type of heat exchanger or hydraulic pressure breaker so as a company, we will be very present. So, the more efficient we can make our product and the better we can support the customers in operating their system in an efficient way, the better it will be. The same goes with when doing that journey and being an important component supplier, which I hope we will be, for us to have sustainable products also from a design perspective and these products to be recyclable or possible to take-back, it is a crucial, because otherwise we will not be able to build the world that we want to be able to.

00:29:13 Paraskevi Striga

In a possible take-back system, that exists in a first phase to the island of Bornholm, and your company is participating as one of the stakeholders, what would be your demands of a take-back system from your perspective as a stakeholder?

00:29:31 Ebba Fjelkner

I think it's to have a value chain that is simple and easy to understand and to work well from the located installation location to the recycler both with the physical goods of course, but also with communications. Understanding the feasibility of the different products, I mean the limitations in terms of recycling is really important to have set that scope.

00:30:03 Ebba Fjelkner

At least as a private consumer, what I hear a lot when talking to friends and family, there is adversity to whenever you hear that you're putting a lot of effort into recycling and then it's not actually recycled. I think that's really something that could bring a negative feeling towards the system. That's something that I think is important that you have a clear definition that this is possible to recycle, this is how it will work and this is what we get out of it. So you get a positive branding out of it rather than a negative inclination.

00:31:40 Ebba Fjelkner

I mean, if we talk more on the refrigerant side, that's something that's we think is very important in Alfa Laval that we want to promote natural refrigerants that are less toxic for the environment has a lower GWP potential, because we shouldn't build efficient systems that they need to refill with the refrigerants, that are not sustainable. So that's something that for us is important. And I think that from a heat pump perspective, when it comes to recycling, as you said, refrigerants make it much more difficult to recycle if you have toxic materials in there.

00:32:21 Paraskevi Striga

And also you focus more on that and you lose the materials like gold or metal, while I think it is important that the focus should be more on designing for modularity and durability of the product and in general the solution is always on how you design the product and it starts with that.

00:33:00 Ebba Fjelkner

Yeah, I completely agree. Yeah. I mean, today, I don't think it's the case so much for heat pumps, but I mean, I know especially electrical components, it feels like they're designed to break down after a few years and maybe that's something we should move away from.

00:33:17 Paraskevi Striga

But do you find it difficult to design a product that can be modular, like can be taken apart and have a spare part so it can last long?

00:33:29 Ebba Fjelkner

I mean we have different types of products. The one I'm working with is extremely modular. You can basically open it in time, you can put in more components to make it to change the performance of it. It's very simple in that way and it's very easy to replace the parts. The issue with that is that it cannot handle as high temperatures and pressures because the fact that it's possible to take apart also makes it less durable resistance to more extreme stress, so we have other types of products which you can't take apart. I mean you can clean it with some type like a CIP solution, but you can't open it. So if you need to do that then you have to replace it.

So there are those kinds of more technical limitations as well. But that's why we have these kinds of products that are little in between. So, they're what we call semi welded, because one part is welded that you can take apart and open every second part of it so you can clean it in a good way.

00:34:49 Paraskevi Striga

And what is the life expectancy of these three different categories of product like?

00:34:58 Ebba Fjelkner

It really depends on the operating conditions. If you have for example, a cooling system, it's very gentle on the product, 30 to 50 years is possible to last. But if you have very high temperatures, very high pressures, acetic acid, things like that, or even sulfuric acid, then the life expectancy of the total product might still be long, but you need to do service on it because the 40 years cannot be without service. So it really depends, I would say. But usually I would say 25 years if we are also doing maintenance, then that's how long it should last.

00:36:07 Paraskevi Striga

OK. And for like the last question, is there anything I didn't ask or if you think that something is important, that you would also want to add? 00:36:31 Ebba Fjelkner

I think it is really important in the design phase to use the right materials. We are quite fortunate in the way that a lot of the materials we're using are what I would call clean alloys, so we don't have so much that we do like surface treatments that you don't have to remove things. So I think that can be an issue with other type of products that you have more of a mixture of materials that are more difficult to recycle. I think we are fortunate in that way that the design of our product inherently is quite simple.

00:37:15 Paraskevi Striga

Yeah, it makes sense because most of your products are not combined with batteries or are electrical.

00:37:25 Ebba Fjelkner

No, exactly. You have a separate pump that pushes through the fluid through the product. So it's kind of an inert system. It just stands there and then things move through it. Yeah, we have some copper metal mixes, so that can of course be trickier to separate.

00:37:53 Paraskevi Striga

But would it be also very valuable for you to have like a relationship with a recycling company that gives you back the copper or the metal, and you can use it again for the production?

00:38:10 Ebba Fjelkner

Exactly. Yes, we even work with that in our own factory. I mean, we have some metal scrap from the process and that we send back, we sell to the producer who recycles it and make new metal from it that we can buy again, so that's a circular system within our own operations.

00:38:36 Paraskevi Striga

And it's just to be clear, you are a company based on Sweden, but the company's strategies that you follow for circularity has also the same effect in Denmark.

00:39:03 Ebba Fjelkner

Our headquarters is in Sweden and we are a Swedish company, but we are also present in Denmark and we are a global company, so we are present approximately in 50 countries. So, we are working on a global scale too. It's not only Swedish legislation that we consider.

9.5 Appendix 5

Interview with SparEnergi

I am currently doing a research of heat pumps and their role in circular economy. I was wondering if you could answer some quick questions, which will help me with my research. I am stating the questions here, it would be great if you could elaborate on these topics, if you have any additional information that I have not included.

Question 1. Do you offer any services, such as consulting, storage, recycling or removal, for heat pumps during their end-of-life phase? And if yes, are these services include recycling for heat pumps?

No, the ENS does not service or store any heat pumps. This is typically handled by service providers such as Bosch, Vaillant, etc. Product service systems are managed by the product providers. However, there are regulations regarding where heat pumps should go at the end of their lifecycle. They are generally sent to recycling sites, where municipalities are responsible for managing the materials in each unit (chemicals, metals, etc.) to determine what can be reused and what must go to landfills or storage sites.

Question 2. Do you have planned any actions for residential heat pumps and recycling? Is there a system that people can repair or recycle the heat pumps?

There are no specific programs for heat pumps at the moment.

Question 3. Do you think that a future take-back system of heat pumps, in which heat pumps can be recycled, repaired or reused would be successful in Denmark?

Reuse programs could exist if they can be cost-effective. Currently, heat pumps are becoming more efficient year by year. For such a program to be implemented, it would need to demonstrate a clear environmental benefit. However, take-back systems are also the responsibility of product providers, as they are tasked with managing product service systems.

Question 4. What could be your role in this possible take-back system if it would be implemented in a small scale, like in the island of Bornholm?

SparEnergi's role is to promote and push the agenda. The Danish Energy Agency, in collaboration with politicians, would need to establish regulations that outline the requirements for such programs. - And that would be formed upon calculations about how long can such a take-back-system or heat pump live? Does it have the same efficiency as before it gets refurbished? (SCOP and COP values) how much refurbishing does such systems need, and what HP's can be allowed to be in such a system? It's important to note that some cooling solutions for these machines are being more and more strict, would it even be possible to refurbish older units which holds illegal chemical compounds?

9.6 Appendix 6

Interview with Jean-Charles Willm from BDR Thermea Group

This interview provides informative feedback on the strategy of BDR Thermea Group, a major European manufacturer of heating, ventilation, and air conditioning (HVAC) systems, towards eco-design and circular economy policy in its heat pump business sector. The interviewed person, responsible for coordinating eco-design activities, Life Cycle Assessment (LCA), EU environment law compliance, and fixability practices, provided insightful opinions on the company's activity and challenges.

BDR Thermea Group manufactures and designs various products including boilers, heat pumps, and solar systems. The interviewee is in charge of the eco-design of the heat pumps in particular across the French market. They explained that sales for heat pumps had witnessed rapid growth in 2021 and 2022 but have recently fallen drastically with government subsidy reforms, gas price reductions, and the high upfront cost to consumers. These changes in the market have led some of the projects for new heat pump development to be put on hold temporarily while the company navigates through this volatility.

In regards to circularity and eco-design principles, BDR Thermea utilizes similar strategies across all of its heat pumps and boilers. These are a focus on modular product design, utilizing recycled materials, and making parts more disassemblable. Notably, newer heat pump models are discovered to have high recyclability—around 85 to 90 percent—owing primarily to the high metal content of materials such as steel, copper, aluminum, and glass. Design efforts also aim to have a high ratio of recycled plastic in the product and make the units more repairable to facilitate longer product life cycles. Refurbishment of old units, however, is not yet being practiced, primarily because of logistical constraints in collection and processing.

Some of the challenges towards driving circularity were mentioned in the interview. Among the foremost issues is the lack of end-of-life data, without which the company cannot properly measure actual recyclability and make proper planning for improvement. The other challenge is that economic factors tend to make cost, energy efficiency, and quality take precedence over some eco-design aspects. Complexity in logistics, particularly when there is refurbishment or take-back schemes that incorporate globally sourced components, also hinders forward progress in this area.

In repair and maintenance, heat pumps produced by BDR Thermea are generally durable and require minimal maintenance. Where problems do arise—such as in expansion vessels or corrosion protection systems—these result from incorrect installation and not a design defect. The firm has developed proprietary repairability indexes to measure how simple it is to fix their products, but those metrics are not industry-standard.dd or publicly published. Installers are intended to have unambiguous service guidelines, but the firm admits there's room to add diagnostics and access to spare parts to be more efficient.

BDR Thermea closely monitors European Union policy developments like the Ecodesign for Sustainable Products Regulation (ESPR) and the Energy Performance of Buildings Directive (EPBD). A key regulation that comes into effect from 2028 will require new buildings larger than 1,000 square meters to declare Global Warming Potential (GWP) values. This will increase demand for timely supply of HVAC products with quantified environmental performance. The company is preparing for these responsibilities with work on environmental product declarations (EPDs) and repairability scores. However, regulatory metrics uncertainty, which has yet to be concluded, places a limitation on the amount of investment that flows into score-enhancing activities.

When asked about the feasibility of take-back and refurbishment programs, the respondent was encouraging about working with recyclers and other parties to develop such programs. Refurbishment had especially good potential for certain components, e.g., printed circuit boards (PCBs), but would require costly investments in test equipment, part coding, and large-scale logistics infrastructure. Funding is a severe short-term impediment to system development.

To the future, the interview reinforced that circular development in the future will depend heavily on the integration of policies and approaches across the European Union to avoid splintered national approaches. Firms like BDR Thermea are waiting until firm and finalised guidelines are set before committing significant resources to build beyond current regulatory standards. Economic conditions across Europe today constrain businesses' ability to take circular design further.

In summary, BDR Thermea's reaction to circular economy measures in the heat pump market is primarily prompted by market forces and regulatory requirements. Though its major building blocks such as recyclability and repairability are already set into product architecture, the company realizes that more profound changes must occur. These include increasing logistics for end-of-life management, data feedback loops, and standard metrics. The interview therefore illuminates both the possibilities and difficulties manufacturers have as they seek to move towards more circular and sustainable HVAC solutions.

9.7 Appendix 7

Interview with João Møller from BEOF

00:00:01 Paraskevi Striga

Can you tell me more about your role in BEOF?

00:00:22 João Møller

My name is João Møller and I've been working at BEOF since October last year. So I'm one of the new people on the team. BEOF's main goal is to supply the island with water and treat the wastewater supply with energy and our electricity and heat, which is very important.

The way we work water there, there are some wells where we get the fresh water from the ground. Wastewater is been pumping to seven different wastewater treatment stations. The electricity comes from different places. We have some windmills and if I remember correctly, there are two solar PV farms and then we also burn some wood pellets, to produce energy when the clean energy is not enough. On this point, it depends who you ask. I would say that's not a clean energy source. But some would say that is CO2 neutral because they plant it again afterwards, so they get from the CO2 neutral source, so that is the line of how sustainable it is. In the heat as well, it's mostly from burning of those tables. There's also collaboration with Bornholm's bioenergy. They received some of the rests from a farming, mostly pig feces and from and use it from to energy and heat. BOFA receives some of the waste from the island and burn part of it. There is also Ronne Vandogvarmer produces heat only for part of Ronne and I think BOFA produces heat for 1/3 of Ronne, so 1/3 of Ronne Vandogvarmer and then the rest of the island is us. That was about BEOF. My part in BEOF is that we are a team that is externally funded, so the main goal of BEOF is those things that I just mentioned, but we have this, the focused or plans, visions to work as sustainable as possible. And one of the ways we do that is by being part of external funded projects mostly from the EU and all of the projects are about sustainability. Basically we are a big team of 11 people and we have 15 different projects right now. Of those 15, I think nine of them are Horizon projects. So those big EU funded projects and I think three are INTERREG and to are something else just internal. I am the project leader of three different projects and Co leader of one of them. There's a group that works with a wastewater projects because they're many of them, apparently. And then another group that is more with district heating and energy. The ones that I have is Audion and synergies, those two projects are basically about data. So we have as we call them prosumers, that are both producing energy and are high consumers of energy that for example prosumer would be someone that have solar PV on the house and have an electrical car, so they produce and they consume more than a normal consumer.

00:07:13 João Møller

So heat pumps is one of the high consumer of energy. So many of them have heat pumps and it's either PV or windmills and then some have electrical cars instead of heat pumps, or both. The idea is to get the data from those prosumers and use it as simulation those days to make a more flexible system. So basically saying, we can see that when on this day that payoff was producing this much, those households were producing that much. So we can say OK, they should not produce more than necessary, so we should stop burning X amount of wood pallets for example. So they need to give more flexibility based on our customer state.

00:08:34 Paraskevi Striga

Are these prosumers participating in their own will or is based on their data profile of energy consuming that is decided that this is a prosumer?

00:08:50 João Møller

They are part of the project or we have visited them and we have installed some Internet of Things devices at their houses, so it's not just any customers. There are customers that wanted to be part of the project and have this extra service that we installed at their homes. So we get the data directly from them. I'm pretty sure we have more prosumers as customers, that would fit and have either electric car or heat pump and produce either with PV or windmills, but those thirty that we have are the ones that came to us and wanted to participate in the project. And another part of this project is that it is about the energy community. The perfect end-goal here would be that people that produce energy that would live close together, they can produce energy and share between them instead of just go to the system, because it's easier to just to get some energy from our neighbor, than someone that lives 6 kilometers away. So those energy communities is something that I find very interesting and now we are searching for more projects to keep working on them. But that that was two of the four projects the other two are more focused on electric cars.

00:14:01 Paraskevi Striga

So very interesting. Both categories of the projects, especially the one with the data, because I think we need a lot of data to transition from linear to circular economy and sustainable solutions. Can you describe more the current status of heat pump adoption in Bornholm? Is there something like funding programs that the consumers can have subsidies or do you see from BEOF's point of view that the consumers want more heat pumps or buying more heat pumps?

00:14:46 João Møller

Yes, OK. From BEOF's point of view, we have two different utilities. We have BEOF's product, which is the district heating and then we have the municipality, that wants people to go greener. There is a talk about it, because if they are still our customers, buying energy from us, it is still a gain for us if they have heat pumps. It took us some time to be able to give the opportunity for our customers to buy EV chargers through us for example. We cannot have EV charges or heat pumps and sell it, but we can have a communication and a partnership with some other companies that do so and then our customers get a better price through us. The district heating is expensive infrastructure and we want people to use it because if people don't use it, we use a lot of resources for something that is for just a very few, so we wanted that many people have the opportunity to use it. But we cannot receive money for it. The district heating has basically to be 0 in the end. Both the district heating and the water and the water treatment. The only place that we can get money for is electricity. It could be a good idea and that where the talk is, to push and have some partnerships for people to get heat pumps and buy energy from us. But then the districting will be more expensive to handle. When we go to the municipality, the municipality have some subsidies and if I'm not mistaken, that's once a year that they open for some money or much less. I've been living in Bornholm for 4 years now and I've seen it three times. It is happening very fast, because there is not much money or it can help just a few people and it's very specific. They want people to change from oil to heat pumps. Because there are still many houses that will heat their households with oil, so right now what we see is the municipality giving this funds. I think they pay over 50% of what you need for to change, so it is a lot of money understand that people are willing to search for the money and be one of the first, but there are not many households that get the opportunity to do so. They come from the municipality, not from BEOF. But if BEOF take the opportunity to sell heat pumps, the incentive will be a cheaper price for our customers, but I don't see us giving money for them to change from whatever to heat pumps.

00:21:31 Paraskevi Striga

OK, I understand. Do you know if from the municipality's perspective except from the subsidies that they give to change to heat pumps, do they collaborate with any of the installers that exist in the island? Or do you have a partnership as well with the installers?

00:21:57 João Møller

No, we do not have. Not yet. That's one of the things that I think belong to the future. We would like to have and this is an open discussion so this is that's why I say I think and not say for sure.

00:22:24 João Møller

What I know from the municipality, they don't have anyone specific either they have those subsidies money but when you get it, you have to find yourself who is going to do the installation and the transition to heat pump.

00:22:49 Paraskevi Striga

Do the users have a choice of the heat pump that they want to install or it is predetermined which model of heat pump and which manufacturer they are going to install?

00:23:01 João Møller

It is their choice. Yes. And I think it also depends of the building, I'm pretty sure many of the houses that are already built have radiators, so it's much more difficult to just take everything off and make an air to air, then just get keep one air to water or ground to water. And then you need some ground stuff. You need some, some space, So it is up for the user. As a matter of fact, I looked into the installers of Bornholm, because I wanted to install a heat pump in my house, and I saw that there were not any installers with expertise in installing heat pumps. I didn't find any at that time.

00:24:19 Paraskevi Striga

I have interviewed one of them, the company is called Flemming Svendsen. They said that they were working with heat pump installation.

So if we want to transition to circular economy, what would you say is the best approach of circularity? And if you can say more about that in relation to heat pumps.

00:25:50 João Møller

I find circularity in general a very interesting topic and I can see here in Bornholm that the company that talks about circularity the most is BOFA. So it's a very different kind of circularity, it is about the waste, but they they have a plan with it and that's their goal. I feel that's very nice. BEOF works a lot as I mentioned with sustainability, but I also see a lot of how can we get more, more windmills, more solar panels in very little of how can we reuse some of the things we have already. We have some influence, some visions based on Kalundborg system I don't know if you if you read about the Kalundborg system. It's a city on the other side of Sealand, on the other side of Copenhagen, where they have some synergies between industry. We have some industry here on Bornholm and we would hope to have more.

So now I get to your point, I want to talk about the Energy Island project. It is right now at the point that is a little uncertain, and I'm very sad about it because I think it's an amazing project, but the idea is to produce 3 to 3.8 GW on Bornholm or just outside of Bornholm and the energy will be transferred to the island and then from Bornholm will be transported in, transformed and transported to Copenhagen and to Germany. With the Energy island, we will get a lot of energy going into Bornholm first. In this, a lot of energy, the idea is that we can use that to an industry park, so industries that need the energy it need clean energy would have would be possible to move to Bornholm and then we can get a lot of new jobs to the island. And these industries can use this green clean energy and on this, there's a lot of ideas of synergies and reuse of resources.

00:30:26 João Møller

I haven't seen anything that this has been our focus yet, but with this big project, there's a lot to talk about it. So what I'm saying here is all visions, plans and hopes is not something that happens right now.

I feel that's very unsustainable right now. So that's why I keep saying that right now is not the focus, but it is this plan especially with the Energy Island project because the Energy Island project is all about sustainability. And in the future to have Bornholm as a green ideal and a center for sustainability, that is the goal we have. I think it's very interesting back in 2018 when they decided to have this goal of zero-waste Island. It is about the resources, but that connects with the heat, with the water and everything in the end. If you reach their goal is only about waste, but is nice to have in your mind that it is not only that. I know that there's need of energy or it is probably produced heat as well and that there are so many things that need heat, especially here, and without the circular thought about circularity in the resources, we will lose some of this precious heat.

00:37:59 Paraskevi Striga

Yeah. So do you see any potential to Bornholm to become more like a model for small scale communities in regards of sustainable heating and in regard of circularity?

00:38:24 João Møller

For sure. And I think that's something that on research we keep getting smaller and smaller and smaller. So even though one home is it's an island with less than 40,000 people. I mentioned in the start that something that interests me a lot is this energy communities or where some houses are a neighborhood would be able to have one battery for example, or have some mean of producing energy and then sharing between them. There are a lot projects that we are working right now, but Bornholm is not that big, so I cannot , if we talk about a big infrastructure or big investment like the Energy Island, I can see the whole island being a center for development of this energy communities and sustainable development lab, basically. I don't think I am alone on this. I think it's it has been a goal with Bornholm between 2015 and 2020 those years prior to the pandemic. They had a lot of work making visions for well, there's, I don't know if you come across it, but there was a project called Bright Green Island. Bright Green Island had eight goals. One of them was a that Bornholm would be CO2 neutral by 2025, but the I think the change of mayors this project has been a little bit forgotten are just putting in action.

But at that time as well as when BOFA came with theirs and now we can see BEOF has this as priorities since 2017 as well with sustainability. So in those years it has been a a major focus and we have been working on that since. So yes, I completed agree. I really, really think that Bornholm can be something that we can just test.A test island we use that a lot today. I think both also used it for the test island for different technologies. Then we can just see OK how does it work here and how can we do this copy paste, which is never a copy paste is always a different things. But how can we implement this that has been that are worked here on the home? How can we implement this in the rest of Denmark in Europe?

00:42:06 Paraskevi Striga

Because you said that Bornholm is like a test bed now for a lot of circular and sustainability solutions, do you see any challenges that still need to be addressed to achieve these solutions? Some common challenges between all these plans that keep Bornholm behind from achieving their goal?

00:42:37 João Møller

I don't want to generalize, but I think the biggest challenge on Bornholm are the people in Bornholm. I am not saying that people don't want this sustainable development, but it is a challenge to say, OK, we are using your waste or we're using your background to test something new. That is is difficult for most people, that they are afraid of the new when it's too close to them. And we see this a lot here in Bornholm unfortunately. And we have elections this year. So it would be a very interesting election year. I'm also a politician, and so now I'm not seeing with new eyes on the problem. And there's a lot of conservatives on the on the island and I never really felt the climate and environment as a really big focus here. Some years ago we have this national elections, they called that the climate election, because that was the biggest subject on the whole election. But here it wasn't even close. So when we talk about the local elections that's happening here this this year, me and some other people from my party, we have it as our first thing, the biggest point on our agenda, but it is not that popular. Of course, if you talk about the environment there say so the so the nature that's something that people usually are very happy for here on the home, many people moved to the island because of it. But when we're thinking about climate and energy, I feel that there is a lot of challenges from the citizens to it.

Besides that it is a poor municipality, and every year we have just cuts and cuts and cuts on our budget. So it is difficult to say, that we want to be a test bed and we're going to use a lot of money, something that hopefully will work. We cannot say that it's not a possibility. So these projects, this money, this testing have to come from outside. That's my team. We are completely external initiated by the EU because all these projects come with some money for people to work on both. I don't know if BOFA are 100% as we are, but much of their salary also comes from those that work on projects, comes from the projects. And even on the municipality there are some external financiered and that's I think that's what we need. We need people who have their job to search for these funds and projects and then come here and then work. We cannot have any hope of sustainable development on Bornholm if the private sector is not interested for. And they need to see this as a an option, an opportunity to develop their own project products more greener or their own industry in workspace.

00:49:07 Paraskevi Striga

Do you think that the geographical position of Bornholm is also a challenge for different projects to be implemented? Is it difficult for some infrastructure, or some manufacturers, and private companies to invest in an island?

00:49:32 João Møller

Both yes and no. Actually, I think there are some very good things about being an island, especially where we are located. We are point of interest because we're so close to so many countries. To go from the Baltic Sea to the North Sea, the only country stopping us, the only country that has some say of what goes by is Denmark and Denmark would have no problems letting a Danish to go through there.

I can use Jensen as an example for private companies in the island. It is the biggest company we have in the island and many people work there, so if they decide to leave from the island, the island will go broke instantly. But the real question is why they are still in the island and what can we learn from that? But I think is where they started this company and its part of their story, and they want to keep it here. But I think on with this development of this green transition, if we cannot provide something different, something new, something that they cannot get just by being in Copenhagen, that's the point of turn. That is the thing that the company would be interested on staying right beside the transformer station for this Energy Island, then having to pay extra for the transport, because there will be some energy that has to be used and that's very interesting for companies.

But both points have a good and bad this about being an island I think is a very interesting as well because we know exactly what is on the island. There is only one connection to Sweden, that's one cable. So if you go to DTU they have something called the power lab, where they have a big wall that televises the island of Bornholm, and we can see exactly how much solar energy is being produced, how much wind energy is being produced and how much is being consumed and how much is we're getting from Sweden. This kind of data for testing and for funds to invest on is very interesting or if we take a sit in Copenhagen, or close in the city of Gentofte, they also have some windmills and the produce and they go in, but they have three other cities around that also use that energy. It's impossible to have a closed system there that you can test something. So that is also a good thing about Bornholm when you talk about being a test island.

For companies can be expensive to be on the island, but they can have a new opportunity with this energy for funding. It's a unique place, but the problem is the conservative part and I think the last point that I want to mention though, when I talk about the difficulties, it is about the current situation of the world and Europe. Our biggest fear in Europe, right now is Russia and we have a new Russia has a different connection to because if you look at the map just under Lithuania, there's a small part of Russia that goes to the Baltics that is directly here. And we are talking about investing lot of money to have this green energy production right beside us. Because we don't want to import gas from Russia. So one of the things that people are most afraid of, even the Danish Government, they know about it and they just agreed for two weeks ago in a new program to send a lot of more soldiers to the island, because that's the first point where Russia would be interested in doing something. Especially if we produce a lot of energy to Germany and to Denmark. So, this is not a positive thing to think about, but it is the reality.

00:56:41 Paraskevi Striga

Also, there is an ongoing program that's called REPowerEU that EU wants to transition from the gas that are having from Russia to electricity and not depending on the gas.

00:57:27 João Møller

I was sorry to interrupt, but I think heat pumps, and those things we need energy for is something that we need. It's very important that we think about when implementing it is where the energy comes from because it really, if you're heating your house with gas or if you heating your house with the heat pumps, that need gas to produce the electricity or it's actually better to use the gas because it's a one step less. But yes, I heard about the REPowerEU and I see that the idea is to just cut the gas.

00:58:39 Paraskevi Striga

I was wondering if BEOF has ever considered of implementing something similar to a take-back system or a more advanced take-back system that does not work only for heat pumps in their end of life, but also has the ability to implement other circular strategies as Repair, or Reuse, and if you ever have considered to collaborate with other stakeholders in the island for this, such as BOFA or the installers.

00:59:48 João Møller

I would say that the company is big and we are 170 people working on BEOF, but I'm pretty sure that this has not been on the talk yet or I never heard from the people that would be responsible for this conversation, I never heard this discussion. There are projects that we work together with BOFA and there's a big interest on searching for more projects with them because we would like to have participation with them. But specific with that we haven't had any projects or any conversation about. I know that they have a project that I worked with them a little. It was about the reuse of refrigerators and washing machines, this kind of stuff, so they have a concessionaire right now. In Denmark, but there is a rule that when you throw something out that is like those electronics, then that's not yours anymore. You cannot use this. It has to be to a specific. It has to go to specific company responsible for that, but you're not able to see someone figuring something out and pick it up and try to repair it. So they did the container for that, do not throw it out, put it here for it to be repaired basically.

01:02:31 Paraskevi Striga

I think it is called REuseLAB and it was in collaboration with FGU.

01:02:36 João Møller

Yes, yes, exactly. I think something like this could happen between BOFA and BEOF and find a new project. But with certainty I can say that it has not been a part yet.

01:03:02 Paraskevi Striga

But you would be positive on a collaboration between those stakeholders?

01:03:08 João Møller

I would. I would for certain. I think more the sustainable approaches we have, it is easier for us in the future to search for funds and get funds for projects and that's one of our big goals. So we can keep doing what we're doing. So if we are investing on heat pumps, we should have something that we can search for money to do something afterwards. Sustainability brings funds as well.

01:04:03 Paraskevi Striga

That's what my thought was because I feel like I see this trend now that we invest more in heat pumps, but we don't consider what happens after these heat pumps will be expired or will be in their end of life, especially the residential heat pumps. I know that the industrial heat pumps can have a life of maybe 50 years and more. But for the residential heat pumps is a perspective that we have not think about yet.

01:04:48 João Møller

We just mentioned just to make a parallel there. The same would be with windmills actually, because there's a lot of talk of that we want windmills, we want Aeolic energy because it's clean, but the parts of the windmill, at least the ones that we have here on Bornholm right now, they cannot be recycled and basically the only thing that we can do them right now was put it underground and we saw some interesting things been doing done in Poland, that they use the wings as the bus stops. It's something just roofing. Just because it has this format, so it's both pretty and nice. And so you can just put it somewhere and then it becomes something, but that's exactly what you're saying, and that's something that we work with. And another thing that we can say with a little bit more certainty, is that it has not been the focus until now, but it should because to have a sustainable workplace, we have to think around. So that's for sure something that should be a topic.

01:06:15 Paraskevi Striga

Yeah, and my thought was also like about before we start implementing something like a solution on recycling, I think the most important thing is to focus on the design process and eco-design. And I find it really important to have a co-design between all the stakeholders and test a take-back system before starting implementing from only one perspective of a stakeholder. What do you think would be your own perspective in this system and what would your main demands would be or you expectations?

01:07:14 João Møller

I don't think if I'm saying this as a BEOF person, but more like if I had something here and I had this process as a citizen and maybe consumer, I cannot see asking the consumers or the customers to do something themselves. They have to have a more passive role in this system.

And this is a difficult question just because I think always when we have to think about a new perspective it's difficult to have everything on one or two minutes, but it's this risk or this process is more like a couple of workshops with a lot of posted notes and really having a conversation with people. One thing that comes up in my mind is that the customer should be serviced for it and should not expect something and it cannot be something that it is too expensive on the point where they think, should they go with sustainability or should they go with the price in their minds. Because unfortunately price always wins when making a decision almost 100% of the time, and that's the harsh reality. But that doesn't mean that it is impossible to do, it's just it has to be a way to do it right. Price and service, I think those are the two focus points. And I guess collaboration between the stakeholders that are involved in the design. If there's something that companies need to do because it has been pointed at them, if there is a decision from politicians that this is how you need to do, someone will have to eat those costs and as soon as you have more stakeholders working together to figure out how to do it, the cost will be cheaper for each instead of one that has to take all the costs.But that's only the economic part. But they did. They do also open doors for more collaboration between them.

01:11:07 Paraskevi Striga

And I feel like now, with the new policy of reporting for circularity, for big manufacturing companies is a point of being in front of their competitors and providing their costumers with more sustainable solutions, while their eco-design their products. So I feel like there is an opportunity here, but I feel like all the parties should be involved in the process.

01:11:52 João Møller

That's very nice.

01:15:18 Paraskevi Striga

As we come to the end of the interview, do you have any other topics that I didn't mention and you think it is important to discuss them in relation to heat pumps and circularity?

01:15:40 João Møller

Yes, the only thing that I would like to just come back and mention a little bit more is about those energy communities, because I really think that's something that is important and needed to keep being an energy island and test island and everything, because we cannot just keep testing small things. We have to test more and more and more different and more ambitious plans with time. If we just test one small addition each time, it's nice we make sure that we have money for the people that are working on the team and we can say that we are doing something good for Bornholm. But I think it's big projects that are very ambitious, that are the ones that can make a difference. The energy communities is more about creating communities and not about delivering services to customers,. But I feel that this is something that can create more opportunities and make us more attractive for external companies, external funding, people wanting to move here and live on the island.