The Challenge of Technological Advancement in Circular Economy.

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Abstract

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Abstract

This thesis explores the challenges of technological advancement in implementing circular economic practices. Employing a qualitative research method based entirely on secondary data analysis. Using Fortum's sustainability report as a primary case study, supported by supplementary documents, the research identifies technological barriers and opportunities in the transition toward circular economy business initiatives. This analysis reveals the intricacy between rapid innovative technology and sustainable resource management.

Highlighting infrastructure limitations and digital integration challenges while acknowledging the knowledge gap that seamlessly limits the effective transition into circular initiatives. The finding demonstrates how companies like Fortum navigate these complexities through strategic investment in enabling technologies to implement a waste-to-energy business model faced with regulatory barriers and bottlenecks from policy and framework that impede business growth.

This research contributes to the growing body of literature on circular economy implementation by providing insight into the technological dimension of circular transition and offering a framework for understanding how companies can effectively utilise technology to overcome barriers to circularity.

Key words
Technological Advancement, Transitioning, Innovative, Sustainability, Framework, Implementation. Fortum, Circular, Economy, framework Business

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1 Introduction

1.1 Background to Study

The study of a circular economy (CE) has gathered considerable attention in recent years as a sustainable alternative to the conventional linear economy, which a “take-make-dispose” model. A circular economy prioritises the continuous utilisation of resources, reduction of waste, and restoration of natural systems (Ellen MacArthur Foundation, 2015). This concept is increasingly regarded as a feasible solution to tackle the urgent environmental issues of resource depletion, climate change, and environmental degradation. Technological advancements are crucial for facilitating the shift to a circular economy, as they offer the tools and innovations required to maximise resource exploitation, improve product lifecycle management, and create new business models (Geissdoerfer et al. 2017, 758). The incorporation of sophisticated technologies into circular economy practices presents problems. The problems encompass technology constraints, substantial initial expenses, regulatory obstacles, and the necessity for systemic alterations in corporate and consumer conduct (Kirchherr et al., 2018, 266).

Finland, a Nordic nation recognised for its dedication to sustainability and innovation, has led the adoption of circular economy ideas. The Finnish government has established high objectives to emerge as a global leader in the circular economy by 2035, to achieve a carbon-neutral society (Sitra 2019). Finland’s national policy for the circular economy emphasises the significance of technological innovation in reaching these objectives. The nation has made sizable investments in research and development (R&D) to promote technological innovations that aid circular economy practices. Finnish enterprises, regardless of size, have actively contributed to this shift, developing technology to create new solutions that align with circular economy concepts.

Fortum Oyj (thereafter Fortum) is one of the leading energy companies in the Nordic region and a pioneer in the application of the circular economy principle in the energy sector. Headquartered in Espoo, Finland, Fortum has built a strong reputation for integrating sustainability into its core strategy. The company operates in electricity generation, district heating and recycling, and waste solutions. The company has created many technologies and business models that enhance resource efficiency, minimise waste, and facilitate material reuse. Fortum’s initiatives in the circular economy are notably demonstrated through its waste-to-energy systems, which transform non-recyclable garbage into energy and raw materials. This not only diminishes the volume of garbage directed to landfills but also aids in the production of renewable energy (Fortum, 2020).

In Europe, the circular Economy Action plans (CEAP) position this technology as vital tools to meet sustainable goal especially in sectors dealing with organic and municipal waste (European Commission 2020, 128) Finland, one of the early adopters of CE strategies has set the target for becoming a carbon neutrality circular economy society by 2035 (Ministry of environment 2021, 12) companies such as Fortum has pioneered power plants. These processes enable the transformation of biomass, municipal solid waste and industrial side streams into syngas, bio-oil and heat (Fortum 2023,6).

Specifically, Fortum's investment in the Otso gasification plant and its circular economy village in Riihimaki demonstrate how energy recovery technology can support both business and environmental goals. The company employs technologies to convert bio-based feedstock into oil, which can substitute fossil fuels, and uses gasification to create synthesis gas from biomass, reducing virgin energy inputs (Fortum 2023,9). These innovations represent not just technological achievement but strategic moves toward a low-carbon and resource-efficient energy model.

However, despite the potential of such technologies, their implementation is not without challenges for companies like Fortum that face regulatory uncertainties, economic constraints and technological complexity systems at scale (Lazarevic & Valve 2027,90). The study aims to explore these challenges within the context of Finland and the EU's strategies, using Fortum as a case study to understand how technology is applied. However, numerous hurdles persist despite the considerable advancements achieved by Fortum and other Finnish enterprises in incorporating technology into circular economy practices. A principal difficulty is the substantial expense associated with the development and implementation of new technology. This is a considerable obstacle, especially for small and medium-sized firms (SMES) that may lack the financial capacity to invest in such technologies (Kirchherr et al., 2017, 265).

A further problem is the difficulty of shifting from a linear to a circular economy. This transition demands both technological innovation and a structural shift in business operations and consumer behaviour. The implementation of circular economy techniques frequently forces organisations to reengineer their goods and processes, a task that can be complex and labour-intensive. Moreover, consumers must be informed and motivated to embrace more sustainable consumption practices, including recycling and reusing products (Geissdoerfer et al. 2017, 758).

Regulatory obstacles are a considerable barrier to the integration of technology within circular economy activities. In numerous instances, current legislation and standards are misaligned with the principles of the circular economy, hindering enterprises from adopting creative solutions. (European Commission 2020, 128) For instance, legislation about waste management and recycling may insufficiently facilitate the implementation of innovative technology for resource recovery. This may establish a regulatory framework that is unfavourable to the implementation of circular economy activities (Kirchherr et al.,2017, 266).

Although technological innovations can substantially improve resource efficiency, reduce waste, and generate new economic prospects. The advancement of digital technologies, including the Internet of Things (IoT) and blockchain, facilitates more effective tracking and administration of resources, assuring optimal material application throughout their lifecycle.

Furthermore, progress in materials science may result in the creation of new materials that exhibit increased durability, recyclability, and environmental sustainability (Geissdoerfer et al., 2017,759).

Finland’s dedication to the circular economy, along with its robust legacy of innovation, establishes the nation as a global frontrunner in this domain. Finnish enterprises such as Fortum exemplify the feasibility of using technology in circular economy practices, notwithstanding the obstacles. Through investment in breakthrough technology and the development of innovative business models, these companies are facilitating a more sustainable future. (Fortum 2023) To fully realise the promise of the circular economy, it is imperative to confront the obstacles that hinder the incorporation of technology into circular economy practices. This requires a cooperative effort among governments, enterprises, and consumers, alongside dedication to ongoing innovation and enhancement.

In conclusion, the incorporation of technological advancements into circular economy practices offers both benefits and challenges. Although technology can improve resource efficiency and reduce waste, substantial prices, regulatory obstacles, and necessary systemic transformations present considerable problems. Finland, through its robust dedication to sustainability and innovation, is at the forefront of tackling these challenges. Companies such as Fortum show the possibility of incorporating technology into circular economy activities, facilitating a more sustainable future. To fully realise the promise of the circular economy, it is crucial to confront the obstacles that hinder the incorporation of technology into circular economy activities. This requires a cooperative undertaking among governments, enterprises, and consumers, alongside a dedication to ongoing innovation and improvement.

Statement of the Problem

The shift from a linear economy to a circular economy (CE) is gradually acknowledged as an essential strategy for attaining global sustainability objectives. The incorporation of technical innovations into circular economy practices poses considerable difficulties that delay their extensive implementation. Although technology can improve resource efficiency, reduce waste, and generate innovative business models, numerous obstacles remain, such as elevated implementation costs, regulatory discrepancies, and the necessity for comprehensive alterations in both business practices and consumer conduct (Kirchherr et al., 2017; Geissdoerfer et al., 2017,758).

These challenges are especially evident in sectors where conventional linear models are firmly established, rendering the transition to circularity difficult and resource demanding.

Finland is a nation recognised for its dedication to sustainability and innovation, which prioritises the circular economy as a fundamental component of its national policy. The Finnish government has established ambitious objectives to attain a carbon-neutral society by 2035, with technological innovation serving a pivotal role in this transition (Ministry of Environment 2021, Sitra, 2019). Nevertheless, Finnish enterprises, particularly prominent firms such as Fortum, have considerable obstacles in utilising technology to comprehensively implement circular economy principles. For example, although Fortum has progressed in waste-to-energy solutions and resource recovery, the substantial expenses associated with sophisticated technologies continue to pose a challenge, especially for smaller companies (Fortum, 2020). Moreover, current regulatory frameworks frequently do not facilitate creative circular practices, hence imposing additional challenges for organisations attempting to implement sustainable solutions (Kirchherr et al., 2017, 264).

The issue is in the disconnection between the capacity of technology innovations to promote circular economy practices and the structural, financial, and regulatory obstacles that hinder their execution. Overcoming these obstacles is crucial for realising the complete potential of the circular economy, both in Finland and worldwide. Failure to address these concerns will impede the transition to a circular economy, hence compromising broader sustainability and resource efficiency initiatives.

Research Objectives

The objective of this thesis is threefold: first, to examine technologies Fortum used for generating energy in Finland's circular economy, regarding sustainable energy production, second, to analyse challenges that Fortum faces in implementing these technologies, thirdly, to explore solutions to address the challenges, aiming to successfully integrate these technologies in Finland's circular economy

1.2 Research Question

How does Fortum implement and utilise energy generation technologies within Finland's circular economy, and what are the key challenges involved with their effective integrations?

Investigative Questions.

IQ1. What energy-generating technologies has Fortum adopted to support circular practice?

IQ2. What barriers hinder the integration of technologies into circular practices in Finland?

IQ3. How can these challenges be addressed to facilitate a smooth transition to a circular economy?

Significance of the Study

This study is significant for its contribution to the expanding understanding of the role of technical improvement in facilitating the transition to a circular economy. As global environmental issues, including resource depletion, climate change, and waste accumulation, increase, the circular economy has become an essential framework for attaining sustainability. The incorporation of technology into circular economy practices is still little investigated, especially in certain nations and sectors. This study examines Finland, a global leader in sustainability and innovation, with Fortum, a pioneering Finnish company, to offer significant insights into how technical advancements might tackle the obstacles of applying circular economy concepts. The results of this study will be relevant to businesses, corporations, researchers and students aiming to advance sustainable practices and address obstacles to circular economy implementation. The report emphasises the significance of systemic modifications, regulatory coherence, and financial investments in facilitating the transition to a circular economy, providing pragmatic recommendations for stakeholders. (Sitra 2023, 5)

Scope of the Study

This study exclusively investigates the impact of technical innovation on addressing difficulties related to the implementation of circular economy practices, specifically in Finland and Fortum. The study examines the technological advancements implemented by Fortum, the financial and regulatory obstacles impeding the incorporation of technology into circular economy practices, and the systemic transformations necessary in business operations and consumer behaviour. (Fortum 2023) The report presents a comprehensive analysis of the Finnish setting and Fortum’s projects, with conclusions that may yield larger insights relevant to other nations and sectors. The study does not intend to deliver a comprehensive worldwide examination of circular economy practices; instead, it concentrates on a unique case study to illuminate important obstacles and potential.

1.3 Delimitations of the Study

This research possesses multiple limitations. The study primarily concentrates on Finland and Fortum, perhaps restricting the applicability of its conclusions to other nations or sectors with varying regulatory, economic, and cultural frameworks. Secondly, the study depends on secondary data and publicly accessible information, which may not fully cover the details of Fortum's operations or the main issues associated with the implementation of circular economy principles. The study lacks primary data collection methods, such as interviews or surveys, which could yield more profound insights into stakeholders' viewpoints, including corporations, researchers and consumers. The study is constrained by its emphasis on technology improvements, representing merely one issue of the wider shift to a circular economy. This study does not comprehensively address other elements, including social, cultural, and economic dimensions.

1.4 Research Method

This study adopts a qualitative research design. Due to limited access to primary data from Fortum, the methodology emphasises the use of secondary data, such as academic journals and articles, and company reports. Academic journals and articles will provide valuable insight into Fortum's adoption of energy generation technologies and their alignment with circular economy principles. Company reports, including Fortum's annual and sustainability reports, will offer in-depth information on the company's strategy and technological initiatives. By leveraging these secondary data sources, this study aimed to gain a comprehensive understanding of the challenges, opportunities, and solutions related to the integration of energy generation technologies in Finland's circular economy.

1.5 Definition of Terms

1. **Circular Economy** (CE): A system designed to reduce waste and optimise resource utilisation by prolonging the lifecycle of products, materials, and resources through recycling, reuse, and regeneration (Ellen MacArthur Foundation, 2015).

2. **Linear Economy**: A conventional economic model characterised by a “take-make-dispose” methodology, wherein resources are harvested, utilised, and subsequently discarded as trash. (Ellen MacArthur Foundation, 2015).

3. **Sustainability**: Fulfilling current requirements without jeopardising the capacity of future generations to satisfy their demands (Brundtland Report, 1987).

4. **Technical Advancement**: The creation and utilisation of new or improved tools, systems, and processes that enhance efficacy, reduce resource consumption and enable innovative solutions to environmental or industrial challenges (Geissdoerfer et al 2017)

5. **Fortum**: A Finnish energy firm that has innovated circular economy principles, especially in waste-to-energy and resource recovery solutions, also reduces carbon emissions and promotes resource efficiency. (Fortum 2021)

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2 Literature Review

The literature evaluation is an essential element of this study, as it offers an in-depth overview of the current information regarding the role of technology innovation in facilitating the shift to the practices of circular economy (CE). Has emerged as a transformative framework for tackling global sustainability issues, including resource depletion, environmental degradation, and climate change, by advocating for the perpetual use of resources, reducing waste, and restoring natural systems (Ellen MacArthur Foundation 2015). The effective execution of circular economy practices is fundamentally dependent on technology innovation, which is essential for enhancing resource efficiency, creating new business models, and addressing systemic obstacles (Geissdoerfer et al 2017, 758).

This chapter is organised to examine the theoretical and empirical aspects of the circular economy, emphasising the role of technology. The chapter subsequently analyses the technological developments driving the shift towards a circular economy, surrounding advancements such as the Internet of Things (IoT), blockchain, artificial intelligence (AI), and sophisticated recycling technologies (Kirchherr et al 2017, 265). The chapter subsequently examines the obstacles related to the incorporation of technology into circular economy practices, including financial limitations, regulatory discrepancies, and the necessity for systemic transformations in business operations and customer behaviour (Geissdoerfer et al 2017, 758).

The literature study examines the influence of policy and regulation on the advancement of circular economy practices, particularly emphasising Finland's national strategy and regulatory framework (Sitra 2019). Furthermore, it analyses various circular business models and their importance across various industries, along with the influence of customer behaviour on facilitating or obstructing the shift to a circular economy. Empirical case studies are examined to present practical instances of circular economy implementation, focusing specifically on Finland and the case study organisation, Fortum (Fortum 2020). The chapter ultimately finishes with a theoretical framework that produces systems theory, innovation diffusion theory, and the resource-based view (RBV) to establish a basis for understanding the interaction between technological progress and circular economy practices.

This literature evaluation aims to identify weaknesses in current research and establish a theoretical and empirical basis for this investigation. This chapter seeks to explain the opportunities and constraints of utilising technology to promote circular economy practices by integrating insights from academic literature, industry reports, and case studies. Additionally, it aims to place these findings within the context of Finland and Fortum, providing significant insights for enterprises and researchers striving to enhance sustainability and resource efficiency.

Conceptual Framework of the Circular Economy

The circular economy (CE) signifies a fundamental transition from the conventional linear economic model, characterised by a "take-make-dispose" methodology, to a framework that prioritises sustainability, resource efficiency, and waste reduction. This section examines the conceptual framework of the circular economy, describing its fundamental principles, comparing it with the linear economy, and analysing its primary drivers and advantages.

2.1 Definition and Principles of the Circular Economy

The circular economy is an economic system designed to eradicate waste and encourage continuous utilisation of resources by maintaining products, materials, and resources in circulation for extended periods through recycling, reuse, and regeneration (Ellen MacArthur Foundation 2015). Different from the linear economy, which depends on the extraction of raw materials, production, consumption, and disposal, the circular economy aims to establish closed-loop systems that minimise waste and continuously reintegrate resources into the economy.

The foundations of the circular economy are founded on three fundamental concepts:

1. **Eliminating Waste and Pollution:** This principle highlights the necessity of creating goods and processes that reduce waste and pollution from the beginning. By reevaluating product design, materials, and manufacturing processes, companies can mitigate their environmental impact and develop more sustainable solutions (Bokken et al 2016, 308).

2. **Sustaining Product and Material Utilisation:** The circular economy advocates for the prolonged use of items and materials via initiatives including repair, refurbishing, remanufacturing, and recycling. This strategy guarantees that resources persist in

the economy for an extended duration, hence diminishing the necessity for raw materials (Geissdoerfer et al 2017).

3. **Regenerating Natural Systems:** The circular economy aims to restore natural ecosystems by reintegrating biological materials into the environment to enhance biodiversity and ecosystem vitality. This idea corresponds with the concept of biomimicry, which derives inspiration from natural processes to develop sustainable solutions (Ellen MacArthur Foundation 2015).

Comparison Between Linear and Circular Economy Models

The linear economy, which has succeeded in global economic systems for ages, is defined by a single flow of resources: raw materials are taken, converted into goods, and ultimately disposed away as trash. This approach is fundamentally unsustainable, as it depends on limited resources and produces considerable environmental harm, including pollution, greenhouse gas emissions, and resource depletion (Kirchherr et al 2017, 265).

The circular economy aims to dissociate economic growth from resource consumption by establishing closed-loop mechanisms that perpetually recycle resources within the economy. This transition necessitates a fundamental revaluation of production and consumption patterns, with the implementation of innovative business models and technology (Geissdoerfer et al 2017, 759). The circular economy tackles environmental issues while providing economic and social advantages, including cost reductions, employment generation, and enhanced resource security (Ellen MacArthur Foundation 2015).

2.1.1 Key Drivers for Adopting Circular Economy Practices

The shift to a circular economy is propelled by a union of environmental, economic, and social determinants. These factors emphasise the necessity and significance of using circular economy techniques to tackle global sustainability issues.

Environmental Drivers:

- **Resource Scarcity:** The exhaustion of scarce resources, including fossil fuels, minerals, and rare earth metals, has intensified the necessity for more effective resource utilisation. The circular economy provides a remedy by encouraging the reuse and recycling of materials, thus diminishing the need for virgin resources (Kirchherr et al 2017, 265).

- **Climate Change:** The linear economy significantly contributes to green-house gas emissions, which propel climate change. The circular economy can substantially decrease carbon emissions and alleviate the effects of climate change by minimising waste and enhancing resource utilisation (Ellen MacArthur Foundation 2015).
- **Pollution and Waste:** The linear economy produces large quantities of waste and pollution, which have a detrimental impact on human health and ecosystems. The circular economy tackles these challenges by reducing waste and facilitating the safe reintegration of materials into the environment (Geissdoerfer et al 2017, 758).

Economic Drivers:

- **Cost Savings:** Implementing circular economy techniques, including resource efficiency and waste reduction, can result in significant cost savings for enterprises. Recycling and reusing materials can reduce production expenses and generate additional revenue streams (Bocken et al 2016, 308).
- **Resource Security:** The circular economy bolsters resource security by diminishing reliance on limited resources, hence softening exposure to price fluctuations and supply chain disturbances (Kirchherr et al 2017, 265).
- **Innovation and Competitiveness:** By promoting the creation of novel technology, business strategies, and goods, the circular economy stimulates innovation. Organisations that implement circular processes can achieve a competitive edge in the marketplace (Geissdoerfer et al 2017, 759).

Social Drivers:

- **Job Creation:** The shift to a circular economy might generate new employment opportunities in sectors such as recycling, repair, and remanufacturing. These positions frequently necessitate specialised labour and can enhance local economic growth (Ellen MacArthur Foundation 2015).
- **Consumer Demand:** Heightened knowledge of environmental concerns has resulted in an escalating consumer demand for sustainable products and

practices. Organizations that adopt the circular economy can satisfy this desire and improve their brand reputation (Bocken et al 2016, 308).

- **Regulatory Pressure:** Governments and international entities are progressively enacting rules and laws to foster sustainability and diminish waste. Regulatory pressures are compelling enterprises to implement circular economy strategies (Kirchherr et al 2017, 265).

Benefits of the Circular Economy

The circular economy has numerous benefits, encompassing environmental, economic, and social advantages. These advantages emphasise the capacity of the circular economy to tackle global ecological issues and foster a more resilient and fairer economic framework.

Environmental Benefits:

- **Reduced Resource Consumption:** The circular economy reduces the demand for virgin resources and lessens environmental deterioration by advocating for the reuse and recycling of commodities (Ellen MacArthur Foundation 2015).
- **Minimised Carbon Emissions:** Circular economy measures, including energy efficiency and waste minimisation, can substantially decrease greenhouse gas emissions and aid in climate change mitigation (Geissdoerfer et al, 2017, 760).
- **Enhanced Ecosystem Vitality:** The circular economy fosters biodiversity and ecosystem health by revitalising natural systems and mitigating pollution (Kirchherr et al 2017 265).

Economic Benefits:

- **Cost Savings:** Circular economy strategies can yield substantial cost reductions for organisations by minimising material and energy expenditures, along with waste disposal costs (Bocken et al 2016, 309).

- **New Revenue Streams:** The circular economy generates prospects for additional revenue, including the selling of recycled materials, refurbished items, and circular services (Ellen MacArthur Foundation 2015).
- **Augmented Competitiveness:** Enterprises that use circular economy principles can get a competitive edge by distinguishing themselves in the marketplace and fulfilling consumer demand for sustainable products (Geissdoerfer et al 2017, 760).

Social Benefits:

- **Job Creation:** The circular economy can generate employment opportunities in sectors like recycling, repair, and remanufacturing, hence fostering local economic growth and enhancing social welfare (Kirchherr et al 2017, 266).
- **Better Quality of Life:** The circular economy can improve people's and communities' quality of life by lowering pollution and encouraging sustainable consumption (Ellen MacArthur Foundation 2015).
- **Social Equity:** By lowering the environmental burden on vulnerable groups and generating chances for inclusive economic growth, the circular economy fosters social equity (Bocken et al 2016, 309).

Challenges to Implementing the Circular Economy

Although it offers significant advantages, the shift to a circular economy presents several problems. These issues highlight the intricacy of transitioning from a linear to a circular economic model and the necessity for systemic alterations in business operations, consumer behaviour, and legislative frameworks.

Technological Barriers:

- **High Costs:** The development and deployment of advanced technologies, including recycling and waste-to-energy systems, can be expensive and necessitate substantial investment (Kirchherr et al. 2017, 266).
- **Technological Constraints**: Certain materials and products pose challenges for recycling or reuse due to technological constraints, impeding the shift towards a circular economy (Geissdoerfer et al. 2017, 760).

Regulatory Barriers:

- **Misaligned Policies:** Current legislation and standards may hinder circular economy initiatives, posing obstacles to innovation and implementation (Ellen MacArthur Foundation 2015).
- **Lack of Incentives:** Companies may be discouraged from implementing sustainable solutions if there are no financial incentives or regulatory support for circular economy activities (Bocken et al. 2016, 309- 315).

Behavioural Barriers:

- **Consumer Resistance:** Consumers may exhibit reluctance to alter their consumption behaviours or embrace circular practices, such as recycling or acquiring refurbished products (Kirchherr et al. 2017, 266).
- **Lack of information:** Insufficient information regarding the advantages of the circular economy may impede its implementation among enterprises and consumers (Geissdoerfer et al. 2017 760-762).

Systemic Barriers:

- **Complex Supply Chains:** The shift to a circular economy necessitates systemic alterations in supply networks, which can be difficult to execute (Ellen MacArthur Foundation, 2015).
- **Collaboration Obstacles:** Realising a circular economy necessitates collaboration among stakeholders, including enterprises, governmental bodies, and consumers, which can be challenging to orchestrate (Bocken et al. 2016, 310).

The conceptual framework of the circular economy offers a thorough comprehension of its principles, advantages, and obstacles. The circular economy provides a sustainable alternative to the linear economic theory by improving resource efficiency, minimising waste, and regenerating natural systems. The shift to a circular economy necessitates surmounting considerable technological, legislative, behavioural, and structural obstacles. Confronting these difficulties necessitates collaboration among stakeholders, technological and business model innovation, and conducive policy frameworks. This chapter will examine the impact of technical breakthroughs on the circular economy, with actual evidence and case studies that illustrate its potential for fostering a more sustainable and resilient economic structure.

2.2 Technological Advancements in the Circular Economy

Technological innovations are crucial for facilitating the shift to a circular economy (CE). Technology acts as a crucial facilitator of circular economy activities by delivering novel solutions for resource efficiency, waste minimisation, and product lifetime management. This section investigates the function of technology within the circular economy, analyses key technologies facilitating this transformation, and showcases case studies of technological advancements in circular economy practices worldwide.

Role of Technology in Enabling Circular Economy Practices

Technology is an essential catalyst for the circular economy, as it delivers the tools and processes required to enhance resource utilisation, minimise waste, and develop innovative business models. The incorporation of modern technology into circular economy practices allows firms to eliminate waste, prolong product lifespans, and reclaim valuable resources from waste streams (Geissdoerfer et al. 2017 761). Moreover, technology enables the monitoring and administration of materials over their lifecycle, guaranteeing efficient and sustainable resource utilisation (Kirchherr et al. 2017 267).

The function of technology within the circular economy can be classified into three primary domains:

1. **Resource Efficiency:** Innovations include enhanced recycling, waste-to-energy, and material recovery technologies that empower enterprises to optimise resource value and reduce waste (Ellen MacArthur Foundation, 2015).
2. **Product Lifecycle Management:** Digital technologies, including the Internet of Things (IoT) and blockchain, facilitate real-time data acquisition and transparency, allowing organisations to oversee and enhance the utilisation of products and materials throughout their lifecycle (Bocken et al. 2016, 311).
3. **Innovative Business Models:** Technology facilitates the creation of novel business models, including product-as-a-service and sharing economy platforms, which encourage the reuse and sharing of products (Geissdoerfer et al, 2017, 761).

2.2.1 Key Technologies Driving the Circular Economy

Multiple essential technologies are facilitating the shift towards a circular economy. These technologies encompass a diverse array of applications, including resource recovery, waste management, digital platforms, and advanced manufacturing.

1. **Internet of Things (IoT):** The Internet of Things (IoT) denotes a network of interconnected devices that gather and transmit data in real time. Within the framework of the circular economy, the Internet of Things (IoT) facilitates the tracking and monitoring of items and materials over their lifecycle, yielding critical insights into their utilisation, maintenance, and end-of-life management (Bocken et al, 2016 311). IoT sensors can be integrated into items to assess their condition and performance, facilitating predictive maintenance and prolonging product lifespans (Ellen MacArthur Foundation 2015).

2. **Blockchain:** Blockchain is a decentralised digital record that ensures transparency and traceability inside supply chains. In the circular economy, blockchain facilitates the tracking of the origin, utilisation, and disposal of materials, thereby ensuring their effective and sustainable usage (Geissdoerfer et al. 2017, 761-765). Blockchain can authenticate the validity and sustainability of recycled materials, offering assurance to customers and businesses (Kirchherr et al. 2017, 267).

3. **Artificial Intelligence (AI):** AI denotes the application of algorithms and machine learning to analyse data and facilitate decision-making. In the circular economy, artificial intelligence can improve resource utilisation, forecast demand, and pinpoint opportunities for waste minimisation (Bocken et al. 2016 311). AI can evaluate data from IoT sensors to discern patterns and trends in product usage, allowing firms to create more lasting and sustainable products (Ellen MacArthur Foundation 2015).

4. **Advanced Recycling Technologies:** Advanced recycling technologies, including chemical recycling and pyrolysis, facilitate the extraction of valuable components from waste streams that are challenging to recycle through conventional processes (Geissdoerfer et al 2017, 761-765). Chemical recycling can decompose plastic waste into its fundamental monomers, which can subsequently be utilised to

manufacture new plastics, hence diminishing the necessity for virgin materials (Kirchherr et al., 2017, 267-270).

5. **Waste-to-Energy Technologies:** Waste-to-energy technologies, including incineration and gasification, convert non-recyclable waste into energy, thereby reducing the quantity of waste sent to landfills and contributing to the production of renewable energy (Bocken et al 2016, 311). Gasification may transform organic waste into syngas, which can be utilised for electricity generation or biofuel production (Ellen MacArthur Foundation 2015).

6. **3D Printing (Additive Manufacturing):** Geissdoerfer et al 2017, 761) state that 3D printing minimizes waste and maximizes resource use by allowing the manufacturing of intricate and personalized goods with less materials. For example, 3D printing can manufacture spare components for items, thereby prolonging their durability and minimising the requirement for new materials (Kirchherr et al. 2017, 267-270).

7. **Biotechnology:** Biotechnology entails the application of biological processes and creatures to create sustainable solutions. Biotechnology can be employed in the circular economy to develop biodegradable products, reclaim resources from trash, and restore natural systems (Bocken et al. 2016, 312). Biotechnology can manufacture bioplastics from renewable resources, thereby decreasing dependence on fossil fuels and mitigating environmental effects (Ellen MacArthur Foundation 2015).

2.2.2 Case Studies of Technological Innovations in Circular Economy Practices

This case study illustrates the implementation of modern technologies in circular economy practices, showcasing their capacity to enhance sustainability and resource efficiency.

Case Study 1: Philips' Circular Lighting Solutions: Philips, a worldwide pioneer in lighting solutions, has adopted the circular economy by creating new lighting products and services that enhance resource efficiency and minimise waste. The company has adopted a product-as-a-service model, wherein users pay for lighting usage instead of product ownership (Ellen MacArthur Foundation 2015). Philips employs IoT sensors to assess the performance and condition of its lighting devices, enabling predictive maintenance and prolonging product lifespans. The company has also developed sophisticated recycling processes to extract valuable components from end-of-life items, thereby diminishing the reliance on virgin resources (Geissdoerfer et al. 2017, 672-765).

Case Study 2: Renault's Circular Economy Initiatives: Renault, a prominent automobile company, has adopted circular economy techniques throughout its operations, emphasising resource efficiency and waste minimisation. The company has implemented a closed-loop recycling system for decommissioned automobiles, wherein elements like metals and plastics are reclaimed and repurposed in the manufacturing of new vehicles (Kirchherr et al. 2017, 276). Renault has invested in sophisticated manufacturing technologies, including 3D printing, to make spare parts and components with low material usage. This method minimizes waste and prolongs vehicle longevity, hence supporting the circular economy (Bocken et al. 2016, 312).

Case Study 3: Unilever's Sustainable Packaging Initiatives: Unilever, a multinational consumer products corporation, has pledged to mitigate its environmental footprint by implementing circular economy principles in its packaging. The company has created innovative packaging solutions, including biodegradable and recyclable materials, to reduce waste and enhance resource efficiency (Ellen MacArthur Foundation, 2015). Unilever employs blockchain technology to monitor the source and sustainability of its packaging materials, thereby guaranteeing transparency and traceability within its supply chain. The company has collaborated with recycling organisations to reclaim and repurpose packaging materials, so reducing the reliance on virgin resources (Geissdoerfer et al. 2017, 758).

Challenges of Integrating Technology into Circular Economy Practices

Although technological improvements possess significant potential for facilitating the transition to a circular economy (CE), their incorporation into CE practices is loaded with difficulties. These problems involve financial, regulatory, systemic, and behavioural aspects, highlighting the difficulty of transitioning from a linear to a circular economic concept. This section examines the primary issues of incorporating technology into circular economy activities, offering a thorough understanding of the obstacles that must be overcome to fully achieve the potential of the circular economy.

Financial Barriers

A major obstacle to incorporating technology into circular economy activities is the substantial expense associated with the development, implementation, and scaling of modern technologies. Numerous circular economy innovations, including advanced recycling systems, waste-to-energy solutions, and digital platforms, impose significant initial investment in research, infrastructure, and equipment (Kirchherr et al 2017, 268). The advancement of chemical recycling technologies, which decompose complex materials into their fundamental components, frequently entails substantial capital investment and operational expenses (Geissdoerfer et al. 2017, 763).

Small and medium-sized firms (SMEs) are especially liable to these financial obstacles, as they frequently lack the resources and access to capital necessary for investing in innovative technology. This results in a gap between giant organizations, capable of investing in circular economy technologies, and smaller enterprises, which may find it challenging to compete in a circular economy environment (Bocken et al 2016, 313). The return on investment (ROI) for circular economy technology may not be instantaneous, as the advantages of resource efficiency and waste reduction typically manifest over an extended period. This may discourage enterprises from implementing circular economy methods, especially in sectors with narrow profit margins (Ellen MacArthur Foundation 2015).

To surmount these financial obstacles, governments and financial institutions must offer incentives and assistance for enterprises to invest in circular economy technologies. This may encompass grants, subsidies, tax incentives, and low-interest loans for enterprises engaged in the development or implementation of circular economy solutions. Moreover, public-private collaborations can significantly contribute to the distribution of financial risks and benefits associated with circular economy innovations, facilitating firms in surmounting initial cost obstacles and expanding their initiatives (Kirchherr et al. 2017, 268).

Regulatory Barriers

A significant obstacle to incorporating technology into circular economy practices is the dispute between current legislation and the principles of the circular economy. Numerous legislative frameworks were established to endorse linear economic models that emphasise economic growth and resource consumption at the expense of sustainability and resource efficiency. Consequently, these restrictions frequently establish obstacles to the implementation of circular economy technologies and practices (Geissdoerfer et al. 2017, 763).

Regulations about waste management and recycling may be insufficient to facilitate the implementation of new technologies for resource recovery. In certain instances, these policies may inhibit innovation by enforcing tough standards or restrictions on the materials eligible for recycling or reuse (Kirchherr et al. 2017, 269). Likewise, product safety and quality regulations may fail to consider the distinct attributes of circular economy products, including refurbished or remanufactured items, so imposing further obstacles for enterprises aiming to implement circular practices (Bocken et al. 2016, 313).

The absence of unified standards and rules, coupled with regulatory misalignment, poses additional problems for enterprises operating in global markets. A corporation implementing a circular economy solution in one nation may encounter regulatory obstacles when seeking to expand its operations in another nation with distinct rules and procedures (Ellen MacArthur Foundation 2015). The dispersion of legal frameworks can impede the extensive adoption of circular economy technologies and restrict their potential impact.

Governments must create policies and standards to overcome these regulatory obstacles and facilitate the transition to a circular economy. This may involve amending current regulations to conform to circular economy concepts, establishing incentives for enterprises to embrace circular practices, and standardising regulations across regions and sectors. Moreover, policymakers ought to collaborate with stakeholders, such as enterprises, researchers, and civil society, to guarantee that regulatory frameworks are pragmatic, efficient, and inclusive (Kirchherr et al. 2017, 269).

Systemic Barriers

The shift to a circular economy necessitates fundamental alterations in corporate operations, supply chain management, and resource utilisation. Implementing these systemic changes is often difficult and demanding, as it necessitates a revaluation of conventional business models, a redesign of products and processes, and the promotion of collaboration among stakeholders (Geissdoerfer et al. 2017, 763).

A primary systemic obstacle to incorporating technology into circular economy activities is the intricacy of supply chains. In a linear economy, supply chains are generally structured to maximise efficiency and cost-effectiveness, frequently compromising sustainability and resource efficiency. Shifting to a circular economy necessitates the reorganisation of supply chains to emphasise resource recovery, waste minimisation, and closed-loop systems (Kirchherr et al 2017, 269). This poses major problems in sectors characterised by extended and difficult supply chains, such as manufacturing and electronics, where several stakeholders participate in the manufacture, delivery, and disposal of items (Bocken et al 2016, 313).

A further systemic obstacle is the necessity for collaboration across stakeholders, encompassing enterprises, governments, consumers, and research institutes. Realising a circular economy necessitates a collaborative endeavour to devise and execute creative solutions, disseminate information and resources, and synchronise incentives and objectives. Nonetheless, cultivating collaboration among varied stakeholders can be challenging, especially in sectors characterised by conflicting interests and agendas (Ellen MacArthur Foundation, 2015).

To surmount these systemic obstacles, enterprises must embrace a comprehensive strategy for circular economy implementation, taking into account the complete lifecycle of products and materials while including stakeholders throughout the value chain. This may involve establishing collaborations with suppliers, customers, and recycling entities, in addition to allocating resources towards research and development to foster innovation and information dissemination (Kirchherr et al 2017 269). Furthermore, governments may significantly contribute to collaboration by establishing platforms and programs that unite stakeholders to tackle shared challenges and opportunities (Geissdoerfer et al 2017 764).

Behavioural Barriers

Alongside financial, regulatory, and structural obstacles, the incorporation of technology into circular economy activities is impeded by behavioural hurdles, especially among consumers and enterprises. The hurdles arise from insufficient awareness, reluctance to change, and cultural perspectives on sustainability and resource efficiency (Bocken et al 2016 314).

A primary behavioural obstacle is customer reluctance to embrace circular economy behaviours, including recycling, reusing, and acquiring reconditioned products. Numerous people are familiar with the simplicity and cost-effectiveness of linear economy products, typically engineered for single-use and subsequent disposal. Altering these consumption patterns necessitates a transformation in thinking and behaviour, which can be challenging to accomplish without adequate education and incentives (Kirchherr et al 2017 266).

Businesses may similarly avoid implementing circular economy techniques due to insufficient awareness or comprehension of the advantages. Businesses may regard circular economy techniques as precarious or unprofitable, especially if they necessitate substantial alterations to current operations or business models (Geissdoerfer et al 2017, 764). Cultural attitudes toward waste and resource utilisation differ significantly among countries and industries, posing additional hurdles for organizations aiming to implement circular practices (Ellen MacArthur Foundation 2015).

To overcome these behavioral obstacles, enterprises and governments must allocate resources to educational and awareness initiatives that advocate for the advantages of the circular economy and foster sustainable consumption and production practices. This may involve supplying customers with knowledge and tools on recycling and reusing products, while creating incentives for firms to use circular practices, such as tax reductions or subsidies (Kirchherr et al 2017, 270). Furthermore, enterprises can utilize digital technologies, including social media and mobile applications, to involve consumers in circular economy initiatives and foster a culture of sustainability (Bocken et al 2016, 270).

The use of technology in circular economy activities poses considerable problems, encompassing financial, regulatory, structural, and behavioural obstacles. These issues underscore the intricacy of shifting from a linear to a circular economic model and the necessity for a collaborative endeavour among stakeholders to surmount these impediments. Overcoming these obstacles necessitates investment in research and development, the establishment of supportive legislative frameworks, collaboration among stakeholders, and the implementation of educational and awareness programs to foster sustainable consumption and production practices. By tackling these difficulties, enterprises and governments may realize the complete potential of the circular economy and establish a more sustainable and resilient economic framework.

The Role of Policy and Regulation in Promoting Circular Economy

The shift to a circular economy (CE) presents not only technological and economic challenges but also policy and regulatory obstacles. Governments are essential in fostering an enabling environment for circular economy practices through the formulation of supportive policies, regulations, and incentives. This section examines the influence of policy and regulation on advancing the circular economy, analyzing global and national policy frameworks, the instance of Finland’s circular economy roadmap, and the obstacles and opportunities related to regulatory alignment.

2.3 Overview of Global and National Policies Supporting Circular Economy

The circular economy has garnered considerable attention from global policymakers as a solution to tackle environmental issues, including resource depletion, climate change, and waste accumulation. Governments at both global and national levels have established laws and regulations to advance circular economy practices, encompassing waste management and recycling objectives as well as incentives for sustainable production and consumption (Kirchherr et al 2017, 270).

Globally, entities like the United Nations (UN) and the European Union (EU) have been instrumental in advancing circular economy principles. The EU's Circular Economy Action Plan, established in 2015 and revised in 2020, delineates ambitious objectives for waste reduction, recycling, and resource efficiency. The strategy encompasses initiatives including more stringent recycling objectives, prohibitions on single-use plastics, and incentives for eco-design and sustainable product innovation (European Commission, 2020). The UN’s Sustainable Development Goals (SDGs), especially Goal 12 (Responsible Consumption and Production), underscore the significance of sustainable resource utilization and waste minimization, in accordance with the tenets of the circular economy (United Nations, 2015).

Numerous countries have formulated their own circular economy strategies and policies at the national level. China, an early proponent of circular economy ideas, enacted its Circular Economy Promotion Law in 2009, emphasizing resource efficiency, waste minimization, and sustainable production (Geng et al 2012, 216). The Netherlands has implemented an extensive circular economy strategy, targeting a complete circular economy by 2050, alongside interim objectives for waste reduction and resource efficiency (Dutch Government, 2016).

These global and national policies establish a framework for advancing circular economy principles; nevertheless, their efficacy is contingent upon adoption and enforcement. The effectiveness of circular economy strategies is often impeded by inadequate stakeholder cooperation, limited finance, and regulatory obstacles (Geissdoerfer et al 2017, 764).

2.3.1 Finland's Circular Economy Roadmap and Regulatory Framework

Finland has established itself as a global pioneer in advancing the circular economy, supported by a thorough national policy and legal framework to facilitate its transition. The Finnish government has established lofty objectives to attain a carbon-neutral society by 2035, with the circular economy being pivotal to this ambition (Sitra, 2019). The circular economy roadmap of Finland, created by the Finnish Innovation Fund (Sitra), delineates a strategy framework for attaining these objectives, emphasizing critical domains such as sustainable consumption and production, waste management, and resource efficiency.

A fundamental element of Finland's circular economy strategy is its emphasis on innovation and collaboration. The government has formed collaborations with enterprises, research organizations, and civil society to devise and execute circular economy initiatives. The Finnish Environment Institute (SYKE) researches circular economy techniques and offers advise to enterprises and authorities (Sitra, 2019). Furthermore, Finland has initiated various programs to foster circular economy innovation, including the Circular Economy Playbook, which offers practical tools and resources for enterprises to implement circular practices (Sitra, 2020).

The regulatory structure of Finland facilitates the transition to a circular economy. The nation has enacted stringent waste management legislation, encompassing prohibitions on landfilling organic waste and establishing recycling objectives for local governments. These policies promote the adoption of sustainable waste management practices, including recycling and composting, by enterprises and consumers (European Environment Agency, 2020). Furthermore, Finland has implemented incentives for enterprises to invest in circular economy technologies, including tax reductions and grants for research and development (Sitra, 2019).

Notwithstanding these endeavors, Finland encounters obstacles in completely actualizing its circular economy objective. A primary difficulty is the necessity for systemic alterations in business operations and customer conduct. Although Finland has advanced in fostering circular economy practices, attaining a completely circular economy necessitates a fundamental transformation in resource utilization and management (Geissdoerfer et al 2017, 764).

2.3.2 Case Studies of Regulatory Successes and Challenges

This collection of case studies illustrates the achievements and obstacles of regulatory frameworks in advancing circular economy practices, offering insights into the influence of policy and regulation on facilitating the transition to a circular economy.

Case Study 1: The European Union's Circular Economy Action Plan: The EU's Circular Economy Action Plan, established in 2015 and revised in 2020, represents a comprehensive policy framework for advancing circular economy practices. The strategy encompasses initiatives including more stringent recycling objectives, prohibitions on single-use plastics, and incentives for eco-design and sustainable product innovation (European Commission, 2020). A fundamental achievement of the EU's circular economy program emphasis on waste management and recycling. The European Union has established lofty objectives for recycling and trash minimisation, aiming to recycle 65% of municipal garbage by 2035. These objectives have catalysed substantial advancements in waste management methods among member states, with nations like Germany and Austria attaining recycling rates exceeding 50% (European Environment Agency 2020). Nevertheless, the EU's circular economy program encounters obstacles, especially with implementation and enforcement. The policy establishes a framework for advancing circular economy principles, but its efficacy relies on the commitment and capability of member states to execute and uphold the laws. The absence of cooperation among member states has impeded the attainment of circular economy objectives (Kirchherr et al 2017, 270).

Case Study 2: The Circular Economy Strategy of the Netherlands: The Netherlands has implemented an extensive circular economy policy, targeting a complete circular economy by 2050, alongside interim objectives for waste reduction and resource efficiency. The policy prioritises essential sectors including construction, agriculture, and manufacturing, with a specific focus on innovation and collaboration (Dutch Government 2016). A fundamental achievement of the Netherlands' circular economy program is its emphasis on innovation and collaboration. The government has formed collaborations with enterprises, research organisations, and civil society to devise and execute circular economy initiatives. The Dutch government has initiated many programs to foster circular economy innovation, including the Circular Economy Innovation Program, which offers funding and assistance for circular economy projects (Dutch Government 2016). Nonetheless, the Netherlands' circular economy concept has obstacles, especially regarding customer behaviour. Although the nation has advanced much in fostering circular economy practices, realising a completely circular economy necessitates a fundamental transformation in resource utilisation and management (Geissdoerfer et al 2017, 759).

2.4 Business Models for Circular Economy

The shift to a circular economy (CE) necessitates technological innovation, supportive regulations, and the creation of new business models that observe circular economy principles. Conventional linear business models, centred on the production, sale, and disposal of items, are unrelated to the objectives of resource efficiency, waste minimisation, and sustainability. Circular business strategies, by contrast, emphasise the perpetual utilisation of resources, prolonging product lifespans, and deriving value from trash. This section examines the principal circular business models, their applications, and the obstacles and opportunities related to their implementation.

Overview of Circular Business Models

Circular business models aim to dissociate economic growth from resource use by establishing closed-loop processes that perpetually recycle resources and products inside the economy. These models underscore the significance of eliminating waste, maintaining the utilisation of products and materials, and restoring natural systems (Ellen MacArthur Foundation 2015). The subsequent examples represent some of the most notable circular business models:

1. Product-Life Extension: This paradigm emphasises prolonging product longevity through tactics like repair, refurbishment, remanufacturing, and upgrading. Extending the lifespan of items enables firms to decrease the demand for fresh resources and mitigate waste (Bocken et al 2016, 314). Companies such as Patagonia and IKEA have adopted product-life extension tactics by providing repair services and selling reconditioned items (Ellen MacArthur Foundation 2015).

2. Sharing Economy: This model encourages the sharing, leasing, or renting of goods and assets as opposed to private ownership. This method optimizes resource consumption and diminishes the necessity for new items (Geissdoerfer et al 2017, 759). Instances of sharing economy platforms encompass Airbnb, facilitating housing sharing, and Zipcar, offering car-sharing services (Bocken et al 2016, 314).

3. Product-as-a-Service (PaaS): In the PaaS model, enterprises maintain ownership of products and provide them as services to clients, who compensate for the utilisation of the product instead of possessing it. This strategy promotes the creation of durable, repairable, and recyclable items, while firms retain responsibility for the product's lifecycle (Ellen MacArthur Foundation 2015). Philips provides lighting-as-a-service, allowing consumers to pay for the utilization of lighting systems instead of acquiring the products directly (Bocken et al 2016, 314).

4. Resource Recovery: The resource recovery model emphasizes the extraction of valuable materials from waste streams and their reintegration into the production cycle. This model diminishes the necessity for virgin materials and curtails waste (Geissdoerfer et al 2017, 760). Organisations such as TerraCycle and Veolia have established resource recovery frameworks through the advancement of recycling technology and closed-loop systems (Ellen MacArthur Foundation 2015).

5. Circular Supply Chains: This approach entails the reconfiguration of supply chains to emphasise the utilisation of renewable, recyclable, or biodegradable materials. Circular supply networks seek to reduce waste and environmental effects during production and distribution (Bocken et al 2016, 314). Unilever has implemented circular supply chain strategies by procuring sustainable raw materials and minimising packaging waste (Geissdoerfer et al 2017, 760).

Case Studies of Companies Implementing Circular Business Models

This compilation of case studies illustrates the implementation of circular business models across diverse industries, showcasing their capacity to enhance sustainability and resource efficiency.

Case Study 1: Patagonia’s Product Lifecycle Extension Model

Patagonia, an outdoor apparel and equipment firm, has adopted a product-life extension approach by providing repair services and promoting the purchase of pre-owned items. The Worn Wear program enables customers to exchange their used Patagonia items, which are subsequently repaired and resold (Ellen MacArthur Foundation 2015). This model enhances the longevity of Patagonia’s products while simultaneously bolstering customer loyalty and brand reputation. Patagonia's advocacy for "buying less and repairing more" aligns its business practices with the principles of a circular economy (Bocken et al 2016, 315).

Case Study 2: The Sharing Economy Model of Airbnb

Airbnb, an international platform for transient accommodations, exemplifies the sharing economy model by allowing homeowners to lease their properties to travellers. This strategy optimises the use of current housing resources and diminishes the necessity for new construction (Geissdoerfer et al 2017, 762). Airbnb's model has transformed the conventional hospitality sector, illustrating the capacity of the sharing economy to generate value from underutilised resources. Nonetheless, the platform encounters challenges, including regulatory oversight and apprehensions regarding its influence on local housing markets (Bocken et al 2016, 315).

Case Study 3: Philips' Product-as-a-Service Framework

Philips has implemented a product-as-a-service model for its lighting solutions, allowing customers to pay for lighting services instead of acquiring the products directly. In this model, Philips maintains ownership of the lighting systems and is accountable for their maintenance, repair, and end-of-life management (Ellen MacArthur Foundation 2015). This strategy motivates Philips to create durable, energy-efficient, and recyclable lighting products, as the firm assumes the expenses associated with product maintenance and disposal. The PaaS model also provides customers with cost savings and flexibility, as they pay only for the lighting services they use (Bocken et al 2016, 315).

Challenges and Opportunities in Implementing Circular Business Models

Circular business models have considerable prospects for sustainability and resource efficiency; yet their implementation poses obstacles. The hurdles encompass financial limitations, regulatory obstacles, and the necessity for systemic alterations in company practices and consumer conduct.

1. Financial Limitations: The shift to circular business models frequently necessitates substantial initial investment in innovative technology, equipment, and processes. Companies implementing the product-as-a-service model may require investments in product design, maintenance systems, and customer support (Kirchherr et al 2017, 267). Small and medium-sized firms (SMEs) may encounter specific obstacles in obtaining the financial resources required to implement circular business models. Governments and financial institutions can offer incentives, including grants, subsidies, and low-interest loans, to assist businesses in adopting circular practices (Geissdoerfer et al 2017, 761).

2. Regulatory Barriers: Current legislation and standards may hinder the adoption of circular business models, posing obstacles to innovation and implementation. Product safety and quality requirements may fail to include the distinct attributes of refurbished or remanufactured products, complicating marketing efforts for firms (Bocken et al 2016, 316). Governments must create rules and standards that conform to circular economy concepts to surmount these obstacles. This may involve amending current legislation, establishing incentives for enterprises to embrace circular methods, and standardising criteria across various areas and sectors (Kirchherr et al 2017, 268).

3. Systemic Changes: The shift to circular business models necessitates comprehensive alterations in business operations, supply chain management, and resource utilisation. Companies implementing circular supply chain models may require collaboration with suppliers, customers, and recycling organisations to establish closed-loop systems (Ellen MacArthur Foundation 2015). Implementing these systemic changes can be intricate and demanding, especially in sectors characterised by extensive and convoluted supply chains. To resolve this issue, firms must create a comprehensive strategy for circular economy adoption, taking into account the complete lifecycle of products and materials while including stakeholders throughout the value chain (Geissdoerfer et al 2017, 761).

4. Consumer Behaviour: The efficacy of circular business models relies on consumer acceptance and engagement. The sharing economy model necessitates that consumers transition from product ownership to sharing or renting, potentially demanding a transformation in thinking and behaviour (Bocken et al 2016, 316). To foster sustainable consumption patterns, businesses and governments must allocate resources to educational and awareness initiatives that advocate for the advantages of circular economy practices. Moreover, enterprises can utilise digital technologies, including social media and mobile applications, to involve consumers in circular activities and foster a culture of sustainability (Kirchherr et al 2017, 270).

Circular business models are crucial for facilitating the shift to a circular economy, as they emphasise resource efficiency, waste minimisation, and sustainability. Models include product-life extension, sharing economy, product-as-a-service, resource recovery, and circular supply chains present substantial opportunities for enterprises to generate revenue while reducing their ecological footprint. The implementation of these models faces hurdles such as budgetary limitations, regulatory obstacles, and the necessity for systemic alterations in business operations and consumer behaviour. Confronting these difficulties necessitates collaboration among stakeholders, investment in innovation, and the establishment of supportive legislative frameworks. By using circular business models, enterprises may enhance the sustainability and resilience of the economic system.

Consumer Behaviour and the Circular Economy

The shift to a circular economy (CE) presents not only technological and economic challenges but also behavioural ones. Consumer behaviour significantly impacts the adoption of circular economy practices by directly affecting demand for sustainable products, engagement in recycling initiatives, and the acceptance of innovative business models such as sharing and product-as-a-service. This section examines the influence of consumer behaviour on the circular economy, the obstacles to sustainable consumption, and the methods to promote the adoption of circular practices among consumers.

Role of Consumer Behaviour in Enabling Circular Economy Practices

Consumer behaviour is a fundamental catalyst of the circular economy, as it dictates demand for products and services and affects the utilisation and management of resources. In a circular economy, consumers are anticipated to transition from linear consumption patterns, defined by the acquisition, utilisation, and disposal of products, to circular consumption patterns that emphasise reuse, repair, recycling, and sharing (Geissdoerfer et al 2017, 765).

Consumer behaviour's participation in the circular economy can be delineated into three primary domains:

1. Sustainable Consumption: Consumers can endorse the circular economy by selecting products that are durable, repairable, and constructed from recycled or sustainable resources. This generates demand for circular products and motivates enterprises to implement circular practices (Bocken et al 2016, 316).

2. Participation in Recycling and trash Management: Consumers are key in recycling and trash management by accurately separating and disposing of garbage, engaging in recycling programs, and endorsing activities that facilitate resource recovery (Kirchherr et al 2017, 271).

3. Adoption of Novel Business Models: Consumers can facilitate circular business models, including the sharing economy and product-as-a-service, by renting, leasing, or sharing items instead of owning them (Ellen MacArthur Foundation 2015).

Altering consumer behaviour is challenging, as it demands a transformation in thinking, habits, and cultural perspectives toward consumption and waste. Numerous people are familiar with the simplicity and cost-effectiveness of linear economy products, typically engineered for single-use and subsequent disposal. Promoting consumer adoption of circular behaviours necessitates efficient education, incentives, and infrastructure to facilitate sustainable consumption (Bocken et al 2016, 316).

Barriers to Sustainable Consumption

Even though the increasing awareness of environmental concerns, various obstacles hinder consumers from embracing sustainable consumption practices. The barriers encompass insufficient understanding, convenience, expense, and cultural perceptions around consumption and waste.

1. **Lacking Awareness:** Numerous customers lack knowledge of the environmental consequences of their purchase habits or the advantages of circular economy methods. Consumers may lack understanding regarding the significance of recycling and the merit of acquiring reconditioned products (Kirchherr et al 2017, 271)..
2. **Cost:** Cost is a substantial obstacle to sustainable consumption. A significant number of consumers regard circular products, including refurbished items or those manufactured from recycled materials, as costlier or inferior in quality compared to conventional products (Kirchherr et al 2017, 271).
3. **Cultural Perspectives:** Cultural perceptions on consumption and waste may impede the implementation of circular processes. In numerous countries, consumption is complicatedly linked to identity and status, resulting in a culture of overconsumption and waste (Bocken et al 2016 318).

Empirical Review: Case Studies of Circular Economy Practices

The shift to a circular economy (CE) is not simply a theoretical notion but a tangible reality being enacted by enterprises, governments, and communities globally. Empirical evidence from actual case studies offers significant insights into the prospects, constraints, and results of circular economy practices. This section analyses global and national case studies of circular economy implementation, emphasising Finland's activities and the contributions of Finnish enterprises, such as Fortum, in promoting circular economy ideas.

Global Case Studies of Circular Economy Implementation

The circular economy has acquired global prominence, with various nations and corporations implementing new strategies to enhance resource efficiency, minimise waste, and foster sustainability. This compilation of case studies showcases effective circular economy projects across many locations and sectors.

Case Study: The Circular Cities Initiative in the Netherlands

The Netherlands excels in the application of circular economy practices, with numerous cities implementing ambitious initiatives in this domain. Amsterdam has established a circular economy roadmap to attain a completely circular city by 2050. The plan emphasises critical sectors including construction, food, and consumer products, featuring programs like urban mining, which involves repurposing materials from deconstructed structures for new construction endeavours (Ellen MacArthur Foundation 2015).

Rotterdam, a Dutch city, has adopted circular economy methods in its port operations, emphasising waste-to-energy and resource recovery. The Port of Rotterdam has collaborated with enterprises to establish a circular hub, wherein waste materials are processed and used in industrial operations, thereby diminishing the reliance on virgin resources (Kirchherr et al 2017, 272).

These initiatives illustrate the capacity of circular economy methods to revolutionise urban landscapes and establish sustainable, resource-efficient communities. Nonetheless, they emphasise the difficulties associated with scaling circular processes, including the necessity for stakeholder participation and the substantial expenses of infrastructure construction (Geissdoerfer et al 2017, 766).

2.4.1 Finland’s Circular Economy Initiatives

Finland has established itself as a global pioneer in the implementation of the circular economy, supported by a comprehensive national plan and innovative efforts by enterprises and communities. The Finnish government aims to attain a carbon-neutral society by 2035, with the circular economy as a fundamental component of this objective (Sitra, 2019).

National Circular Economy Roadmap: The Finnish Innovation Fund (Sitra) created Finland's national circular economy roadmap, which provides a strategic framework for the country's transition to a circular economy by 2035. The roadmap emphasises critical domains including sustainable consumption and production, waste management, and resource efficiency (Sitra 2019). The plan highlights the significance of innovation and collaboration, with projects like the Circular Economy Playbook, which offers practical tools and resources for businesses to implement circular practices. The roadmap emphasises the significance of digital technologies, including IoT and blockchain, in facilitating circular economy practices (Ellen MacArthur Foundation 2015).

Helsinki's Circular Economy Strategy: Helsinki has formulated a circular economy strategy to achieve full circularity by 2050. The strategy emphasises critical sectors, including building, food, and mobility, with projects like urban farming, which cultivates food in urban environments to minimise transit and waste (Sitra, 2019). Helsinki has adopted circular economy principles in its construction sector, exemplified by the Kalasatama neighbourhood, where components from deconstructed buildings are repurposed for new construction projects. The city has established a circular economy hub, facilitating collaboration among entrepreneurs, researchers, and policymakers to devise and execute circular solutions (Kirchherr et al 2017, 272).

Fortum's Circular Economy Initiatives: Fortum, a Finnish energy firm, has been at the forefront of incorporating circular economy principles into its operations. The company has created many technologies and business models that enhance resource efficiency, minimise waste, and facilitate material reuse (Fortum, 2020). Fortum’s waste-to-energy systems transform non-recyclable garbage into energy and raw materials, diminishing landfill waste and aiding in the production of renewable energy. The company has invested in innovative recycling technologies, including pyrolysis and gasification, to extract valuable resources from waste streams (Ellen MacArthur Foundation 2015).

Fortum's circular economy initiatives exemplify the capacity of technology to enhance sustainability and optimise resource efficiency. However, they emphasise the difficulties associated with scaling circular practices, including the substantial expenses of technology deployment and the necessity for regulatory assistance (Geissdoerfer et al 2017, 766).

Challenges and Opportunities in Circular Economy Implementation

The case examples illustrate the potential of circular economy techniques to enhance sustainability and resource efficiency, while also underscoring the problems associated with implementation. These hurdles encompass financial limitations, regulatory obstacles, and the necessity for systemic alterations in corporate practices and consumer conduct.

1. Financial Constraints: The establishment and execution of circular economy activities frequently necessitate substantial initial investment in novel technology, equipment, and processes. The advancement of sophisticated recycling technologies, like pyrolysis and gasification, can be expensive and necessitate significant capital investment (Kirchherr et al 2017, 266). Small and medium-sized firms (SMEs) may encounter specific obstacles in obtaining the financial resources required to implement circular processes. Governments and financial institutions can offer incentives, including grants, subsidies, and low-interest loans, to assist businesses in adopting circular practices (Geissdoerfer et al 2017, 761).

2. Regulatory Barriers: Current legislation and standards may hinder the adoption of circular economy methods, obstructing innovation and implementation. Regulations pertaining to waste management and recycling may insufficiently facilitate the implementation of new technologies for resource recovery (Ellen MacArthur Foundation 2015). Governments must create laws and standards that conform to the concepts of a circular economy to surmount these obstacles. This may involve amending current legislation, establishing incentives for enterprises to use circular practices, and standardising criteria across various areas and sectors (Kirchherr et al 2017, 268).

3. Systemic Changes: The shift to a circular economy necessitates comprehensive alterations in corporate operations, supply chain management, and resource utilisation. Companies implementing circular supply chain models may require collaboration with suppliers, customers, and recycling organisations to establish closed-loop systems (Bocken et al 2016, 320). Implementing these systemic changes can be intricate and arduous, especially in sectors characterised by extensive and convoluted supply chains. To resolve this issue, firms must embrace a comprehensive strategy for circular economy implementation, considering the complete lifecycle of products and materials while including stakeholders throughout the value chain (Geissdoerfer et al 2017, 761).

Empirical evidence from international and national case studies illustrates the capacity of circular economy methods to promote sustainability, resource efficiency, and economic growth. The adoption of circular processes faces problems such as financial limitations, regulatory obstacles, and the necessity for systemic alterations in business operations and consumer behaviour. Confronting these difficulties necessitates cooperation among stakeholders, investment in innovation, and conducive policy frameworks. By analysing successful case studies, businesses and governments may realise the complete potential of the circular economy, fostering a more sustainable and resilient economic framework.

2.5 Theoretical Framework

The shift to a circular economy (CE) is a complex and varied endeavour necessitating a strong theoretical framework to inform research and practice. This section presents the fundamental theories that support the circular economy, encompassing systems theory, innovation diffusion theory, and the resource-based view (RBV). These ideas offer a framework for comprehending the interaction among technical progress, business models, policy, and consumer behaviour in facilitating the circular economy.

2.5.1 Systems Theory

Systems theory serves as a fundamental framework for comprehending the circular economy, highlighting the connectivity and interaction of diverse components within a system. Within the framework of the circular economy, systems theory points out the necessity of creating closed-loop systems that perpetually recycle resources into the economy, hence reducing waste and environmental repercussions (Meadows 2008).

Systems theory asserts that all elements of a system are interrelated and mutually influential. In the circular economy, alterations in one domain, such as product design or waste management, can induce cascading impacts throughout the entire system (Geissdoerfer et al 2017, 761). Systems theory highlights the significance of feedback loops, wherein the outputs of a system are reintroduced as inputs. In the circular economy, feedback loops are essential for establishing closed-loop processes, wherein waste resources are repurposed or recycled to manufacture new products (Ellen MacArthur Foundation 2015).

Systems theory acknowledges that a system's behaviour frequently exceeds the cumulative effect of its components. In the circular economy, the collaborative efforts of firms, consumers, and policymakers can provide emergent features, such as resource efficiency and sustainability, unattainable by individual entities alone (Kirchherr et al 2017, 269).

Application to the Circular Economy

Systems theory offers a framework for comprehending the circular economy as a complex system, wherein many components, including technology, business models, legislation, and consumer behaviour, interact to produce sustainable outcomes. Advanced recycling methods facilitate the recovery of valuable materials from waste streams, establishing a feedback loop that diminishes the reliance on virgin resources (Geissdoerfer et al 2017, 761). Systems theory emphasises the necessity of constructing circular economy systems that are robust and flexible in the face of change. Businesses can employ systems thinking to create goods and processes that are adaptable to evolving market conditions or regulatory demands (Ellen MacArthur Foundation 2015).

2.5.2 Innovation Diffusion Theory

The innovation diffusion hypothesis, created by Everett Rogers, offers a framework for comprehending the dissemination and adoption of innovative technologies and practices within a society or organisation. Within the framework of the circular economy, innovation diffusion theory serves to examine the adoption of circular economy technologies and practices, including enhanced recycling, waste-to-energy, and product-as-a-service models (Rogers 2003).

The innovation diffusion hypothesis delineates five steps in the adoption process: knowledge, persuasion, decision, implementation, and confirmation. In the circular economy, firms and consumers must first recognise circular economy practices, assess their advantages, choose to adopt them, execute them, and verify their efficacy (Geissdoerfer et al 2017, 762). The innovation diffusion theory classifies adopters into five categories: innovators, early adopters, early majority, late majority, and laggards. In the circular economy, innovators and early adopters are typically enterprises and consumers inclined to embrace risks and experiment with novel technology and processes, whereas laggards exhibit resistance to change (Ellen MacArthur Foundation 2015).

The innovation diffusion hypothesis delineates various elements that affect the acceptance of innovations, such as relative advantage, compatibility, complexity, trialability, and observability. In the circular economy, these characteristics can influence the efficacy or ineffectiveness of circular economy technology and practices (Kirchherr et al 2017, 270).

Application to the Circular Economy

The innovation diffusion theory offers a framework for comprehending the adoption of circular economy technologies and practices, including enhanced recycling, waste-to-energy, and product-as-a-service models. Businesses can employ innovation diffusion theory to ascertain the determinants affecting the adoption of circular economy practices, including the comparative benefits of recycling versus landfilling and the alignment of circular practices with current business models (Geissdoerfer et al., 2017). The innovation diffusion hypothesis emphasizes the significance of communication and social networks in facilitating the adoption of circular economy techniques. Businesses can utilize social media and various communication channels to promote awareness of the advantages of circular economy practices and foster their acceptance among early adopters and the early majority (Ellen MacArthur Foundation 2015).

2.5.3 Resource-Based View (RBV)

The resource-based view (RBV) is a strategic management model that highlights the significance of a firm's resources and skills in attaining competitive advantage. Within the framework of the circular economy, the Resource-Based View (RBV) explains how enterprises might utilise their resources and capacities to implement circular economy practices and derive value from waste (Barney 1991, 100).

The Resource-Based View (RBV) asserts that companies can get the competitive advantage by utilising valuable resources, including technology, knowledge, and relationships. In the circular economy, important resources encompass innovative recycling technologies, proficiency in sustainable product design, and collaborations with suppliers and customers (Geissdoerfer et al 2017, 763). The Resource-Based View underscores the significance of unique resources that are difficult for competitors to replicate or replace. Within the circular economy, uncommon resources encompass patented recycling technologies, distinctive waste streams, and specialised expertise in circular business models (Ellen MacArthur Foundation 2015).

The Resource-Based View emphasises the significance of resources that are challenging to reproduce or duplicate. In the circular economy, unique resources encompass intricate supplier networks, robust brand reputation, and profound customer ties that facilitate circular behaviours (Kirchherr et al 2017, 270).

Application to the Circular Economy

The Resource-Based View (RBV) offers a framework for comprehending how enterprises might utilise their resources and skills to implement circular economy practices and derive value from waste. Businesses can leverage their experience in sustainable product design to create durable, repairable, and recyclable products, so establishing a competitive advantage in the market (Geissdoerfer et al 2017, 763).

RBV emphasises the significance of strategic alliances in facilitating circular economy activities. Businesses can collaborate with suppliers, customers, and recycling entities to establish closed-loop systems that reclaim valuable materials from waste streams and reintegrate them into the production cycle (Ellen MacArthur Foundation 2015).

Integration of Theories in the Circular Economy

The combination of systems theory, innovation diffusion theory, and resource-based view (RBV) offers a holistic framework for comprehending the circular economy. Systems theory highlights the interrelatedness and mutual reliance of many elements within the circular economy, whereas innovation diffusion theory offers perspectives on the assimilation of circular economy technologies and methodologies. The Resource-Based View emphasises the significance of utilising resources and capabilities to attain a competitive edge in the circular economy.

1. Interconnectedness and Adoption: The integration of systems theory and innovation diffusion theory facilitates an understanding of how the adoption of circular economy practices impacts the entire system. The implementation of advanced recycling technologies by pioneers can establish feedback loops that diminish waste and resource usage, hence affecting the actions of other participants in the system (Geissdoerfer et al 2017, 763).

2. Resource Leverage and Competitive Advantage: The Resource-Based View (RBV) and systems theory may be synthesised to comprehend how enterprises might exploit their resources and capabilities to establish a competitive advantage within the circular economy. Businesses can leverage their proficiency in sustainable product design and collaborations with suppliers to create circular products that are challenging to replicate, thereby establishing a competitive edge in the market (Ellen MacArthur Foundation 2015).

3. Innovation and System Resilience: The integration of innovation diffusion theory and systems theory may explain how innovation enhances the resilience of circular economy systems. The implementation of emerging technologies, like IoT and blockchain, might enhance the efficiency and transparency of circular supply chains, hence increasing the system's resilience to disruptions (Kirchherr et al 2017, 270).

The theoretical framework of systems theory, innovation diffusion theory, and resource-based view (RBV) offers a solid basis for comprehending the circular economy. These theories emphasise the interrelation of several elements within the circular economy, the determinants affecting the implementation of circular economy practices, and the significance of utilising resources and capacities to attain competitive advantage. By synthesising these theories, researchers and practitioners can cultivate a holistic comprehension of the circular economy and formulate solutions that enhance sustainability, resource efficiency, and economic growth.

3 Research Methodology

This study employs a quantitative approach to deliver a thorough overview of technical breakthroughs in the circular economy. A case study methodology is utilised to analyse Fortum's involvement in embracing technology breakthroughs that facilitate circular economy practices in Finland. Qualitative research is suited and ideal for this study it is aimed at understanding the meaning and actions that guide individuals or groups. This is not a single technique, but the defined goal researchers seek to achieve. The central focus of this qualitative research is clarification, understanding of a suitable and appropriate theoretical understanding that would guide the researcher in understanding the meaning (Lichterman 2021, 585-586). This approach permits researchers to explore issues in depth, understanding the value and efforts of social and organisational trends (Sarjito 2024, 4).

In this qualitative study, the secondary data will be appropriate since it offers an effective and practical means of analysing complex topics without the need for primary data collection (Sarjito 2023, 298). Secondary data are data that are already available or collected, processed, and analysed for purposes other than the recent research, but can be used to address new research questions. This approach allows researchers to utilise existing data, making the research process more efficient while still obtaining relevant information specifically to address the research goal (Johnston 2014, 620-621).

In qualitative research, when using secondary data, the focus shifts from traditional data collection methods to analysing existing materials like academic journals, company reports or relevant documents. Researchers interpret these sources to understand the motives and contexts that drive actions and decisions. This process includes applying the same standard of interpreting the validity and the richness of this source, ensuring that the secondary data used reflects the perspective and experience of the subject organisation involved (Sarjito 2024, 4-5).

When examining the integration of energy generation technologies within Finland's circular economy, using secondary data provides a comprehensive understanding of the topic. By looking into academic articles, company reports, and secondary data, it allows for an in-depth exploration of Fortum's technological practices, their alignment with the circular economy principles and the challenges and opportunities within the field. This approach offers valuable insight into long-term trends, policy Impact on technological effectiveness.

3.1 Research Design

I have designed this research to follow the guidelines by (Creswell 2016) for conducting qualitative research using secondary data (Creswell 2016), identify several key steps in the process, which ensure that the research is pushed hard and aligned with the research questions (see Figure 1). The following section outlines various steps, for a brief explanation of each and detailing how they are applied in this study.

Figure 1

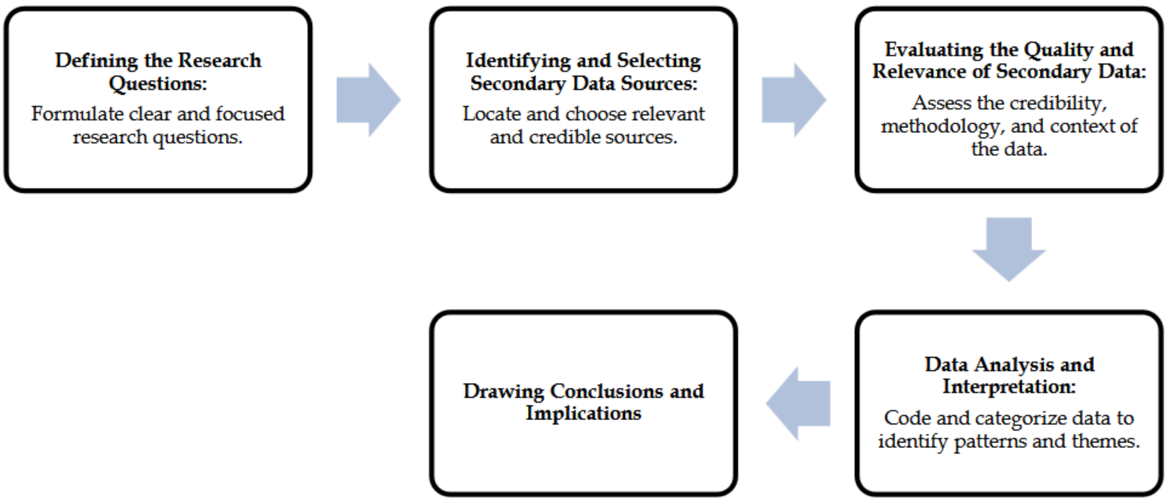


Figure 1. Steps in conducting qualitative research with secondary data (Creswell, 2016).

Defining the Research Question.

The first step in qualitative research is to clearly define a research question, which guides the entire study and helps in selecting and analysing secondary data sources. According to (Creswell 2018). The research question should be aligned with the purpose of the study and focus on specific issues that need to be explored. In this research, the central question focused on how Fortum implement and utilises energy generation technologies within Finland's circular economy, and the key challenges and solutions for effective integration

Table 3.1

Investigative Questions	**Theoretical Framework**	**Research Methods**	**Solution and Recommendations**
IQ1 What energy generation technologies has Fortum adopted to support circular practices?	Chapters 2 & 4 Key technology driving the circular economy practice.	Qualitative Research: Secondary Data	Chapter 4 & 5
IQ2 What barriers hinder the integration of the technologies into circular practices in Finland?	Chapter 2 & 4 Challenges of integrating technology into circular practice	Qualitative Research Secondary Data	Chapter 4 & 5
IQ3 How can these challenges be addressed to facilitate a	Chapter 4 Overview of global policies supporting a circular economy	Qualitative Research Secondary data	Chapter 4 & 5

smoother transition to a circular economy?			

Identifying and Selecting Secondary Data Sources.

Researchers must identify and select appropriate secondary data sources that are relevant to the research questions. These sources should be diverse, credible, and provide different perspectives on the topic in this study, secondary data drawn from academic journals, company reports, and policy documents related to Fortum's energy generation technologies and integration into Finland's circular economy.

Table 3.2

Date	Data type	source	Relevant to study
2019 2020 2021 2022 2023	Sustainability Report	https://www.fortum.fi	Provide relevant information on yearly data that relates to operational dealings, both on sustainability, community development projects, waste recovery and technological innovation, and plans.
2020	Biodiversity Action Plan	https://www.fortum.fi	The Fortum biodiversity manual aimed to improve biodiversity in operations and technology.
2021	Fortum Climate Change	https://www.fortum.fi	This document is used to assess the canon neutrality of

			their operation, analyse plans for improving renewable energy
2022	Electrification Investment	https://www.fortum.fi	Document to evaluate Fortum infrastructure and industrial electrification
2019	Finland 2030 Sustainability Goal	Article	An evaluation of Finland’s sustainable development policy and goal for 2030
2022 2023	CDP Questionnaire	https://www.fortum.fi	Use to provide methodological value of the board’s oversight of climate-related issues

Evaluating the Quality and Relevance of Secondary Data

It is important to carefully evaluate the quality and value of the secondary data. (Cresswell 2016). Advice assessing the reliability of the data source, the methodology used in the original report and the context in which the data was collected in this study, the reliability of company reports, and academic sources will be carefully assessed to ensure the data aligns with research objectives.

3.2 Data Analysis and Interpretation

After selecting and evaluating the secondary data, the next step is to analyse it (Creswell 2016). Emphasise the importance of categorising data to identify pattern themes and insights relevant to the research question for this kind of research thematic analysis with employed to extract key themes from the report, and academic literature identified from the Steps 2 and 3 above.

3.3 Drawing Conclusions and Implications

the last step will require making findings from the data analysis and making conclusion this conclusion should address the research questions and be compared with existing theories frameworks in this study, the funding will be analysed to assess how fortum technologies are being integrated into Finland circular economy the challenges encounter and likely solution providing suggestions for stakeholders and businesses.

3.4 Ethical Considerations

This study complies with ethical research standards, and secondary data collected where used for research purposes only. The research adheres to ethical standards established by pertinent academic and regulatory bodies, guaranteeing data integrity and responsible dissemination of results.

However, the use of AI ChatGPT and Grammarly must be acknowledged for grammar checking language refinement this tools where employed only to enhance clarity and readability of my writing, while all intellectual content, research analysis and conclusions remain entirely my own work, the AI assistance was limited to improving language, corrections of spellings, and aid in the process of writing this research study.

4 Data Analysis and Discussion

This chapter analyses and interprets secondary data gathered to answer the investigative questions concerning the challenges and progress in technology adoption for circular economy practices in Finland. The analysis corresponds with the study's aims, investigating Fortum's technological advancements, financial and legal obstacles, and the systemic transformations necessary for moving to a circular economy. The chapter encompasses descriptive analysis, with data organised in tables for clarity.

IQ1. What energy generation technology has Fortum adopted to support circular practices?

Based on the data gathered from Fortum sustainability reports and supporting documents for this research, the company has invested in the following technologies to implement several innovative energy generation technologies to support circular economy practices

Table 1

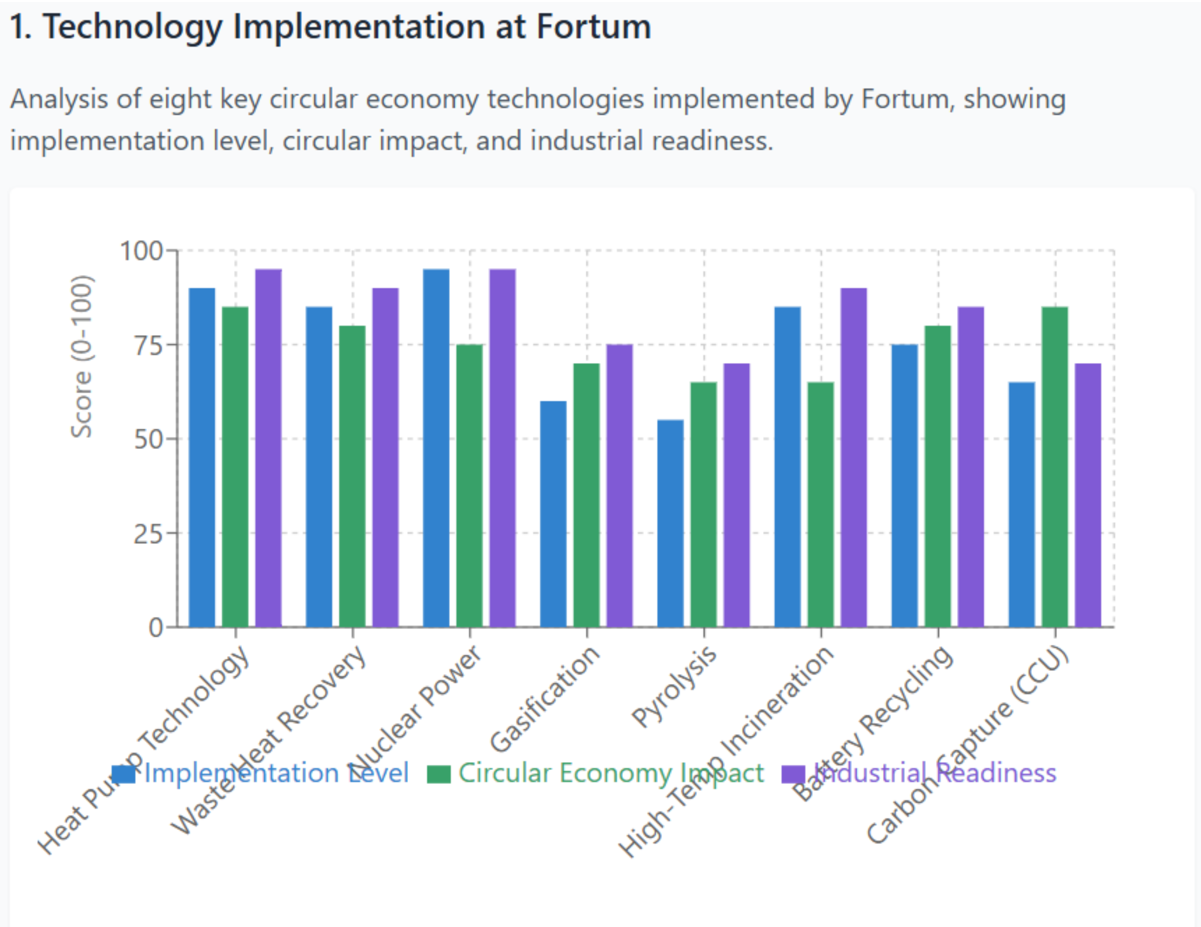
Technologies	**Implementation**	**Circular impact**	**Key findings**
1 Heat Pump Technology	Fortum has invested heavily in heat pump technology to utilise waste effectively.	This facility reduces approximately 40% of heating needs while reducing CO2 emissions by around 400,000 tonnes	This presents a direct application of the circular economy principle by capturing and reusing energy that would have been wasted
2 Waste Heat Recovery Systems	This captures and utilises heat efficiently from waste from various sources	Waste heat from municipal sewage is repurposed to provide a carbon-	This innovative system transforms waste into resources,

		free heating solution	representing a fundamental circular economy principle
3 Nuclear Power as a CO2-free Base	Loviisa nuclear plant is licensed to operate until 2050	Nuclear power provides a stable, CO2-free electricity source that supports other circular initiatives	Fortum reported that 98% of their power generation is CO2-free as of 2023, ensuring a foundation for sustainable circular practice
4 Gasification Pyrolysis Technologies	Fortum developed waste-to-energy conversion through gasification and pyrolysis technologies	These technologies convert waste into syngas, bio-oil and char that can be used for energy production or raw materials	These processes enable a sustainable alternative to traditional incineration by extracting more value from waste materials
5 High-Temperature Incineration with Energy Recovery	Fortum operates high-temperature incineration plants with an advanced emission control system	The facility recovers energy from waste while minimising environmental impact through	This represents a transitional technology that bridges traditional waste with the

		rigorous emission management	circular economy principle
6 Battery Recycling Technologies	The use of mechanical and hydrometallurgical methods for recycling battery materials	A hydrometallurgical plant recovers essential materials like lithium, nickel, cobalt and magnesium	This technology supports a circular economy by keeping valuable materials in circulation and reducing the environmental impact of battery production
7 Carbons Captured on Utilisation (CCU)	This technology was launched in April 2022 to capture emissions from waste incineration	Transformed captured CO2 into high-quality raw materials, reducing reliance on fossil-based resources.	This innovative approach converts what would be waste emissions into valuable industrial input, creating a circular flow of carbon.

Fortum's technology approach demonstrates a sophisticated understanding of the circular economy principles by investing in technology such as heat pump technology, with a heat recovery system, nuclear power as a CO2-free foundation, gasification technology, pyrolysis system, high temperature incineration with energy recovery, battery recycling technology and carbon capture and utilisation. This capital-intensive project is what Fortum invests in locations like Espoo and Kirkkonummi, to convert waste into heat that is channelled into residential and commercial buildings. these technologies create a circular energy recycling that doesn't merely sequester emissions but transforms waste into reusable resources. These technologies from Fortum have collectively created a system of circular loop that minimises waste, reduces the environmental impact of this waste and effectively maximises the retention of resource value.

Figure 1: Technology implementation (Fortum sustainability report 2023)



Technology implementation findings from Fortum.

Most mature technology: Heat pump technology, waste heat recovery, and nuclear power have the highest implementation level 04 (85-95% and industrial readiness

Highest circular impact: Haet pump technology carbon capture and waste heat recovery show the greatest circular economy impact (80-85%)

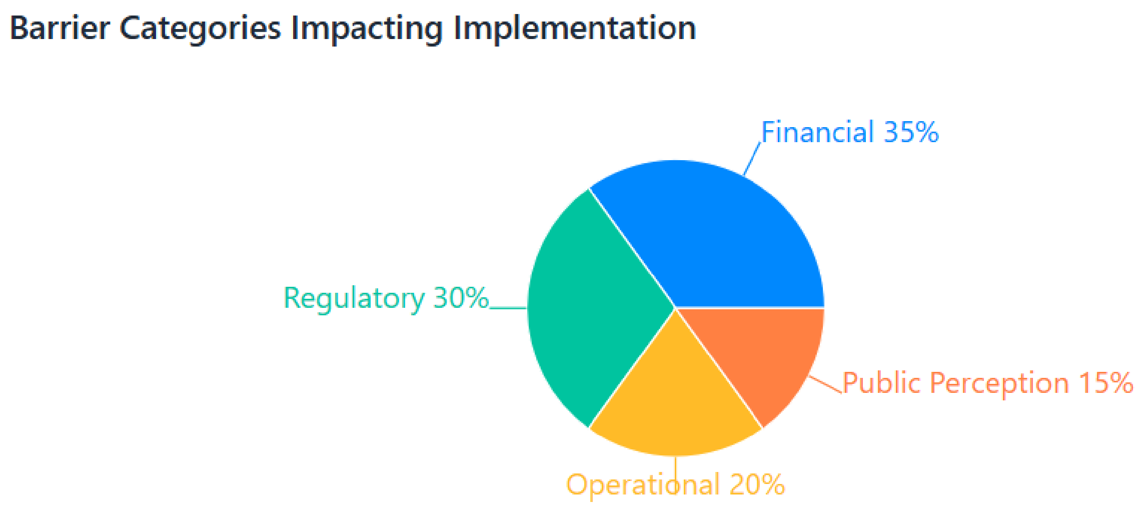
Emerging technology: gasification and pyrolysis show lower implementation and readiness levels (55-60%), indicating an opportunity for future industrial adoption

The above picture shows the Fortum technologies integration into circular practice to track the implementation and circularity of each of the technologies, It shows the readiness of each of the technologies, the implementation stage and circularity progress.

IQ2. What are the barriers hindering the integration of technologies into circular practices in Finland?

This qualitative research analysis reveals several significant barriers in (Figure 2) that can impact the implementation and integration of circular technologies in Finland.

Figure 2: (Fortum sustainability report 2023)



Transition to a circular economy faces challenges that limit the full integration of innovative technologies, like those Fortum has implemented to integrate circular practices. Despite the reputation Finland has built as an environmental leader, the implementation of circular technologies encounters complex issues across multiple domains. Financial constraints represent the most emphasised issues, with capital-intensive cost of investing in technologies, which impedes the adoption of advanced technologies like gasification and pyrolysis. Regulatory processes also create a bottleneck to further increase the operational challenges that businesses face, with limited resources and a knowledge gap. All these are challenges that businesses encounter in adopting circular economy practices. I have carefully analysed this below

Table 2

1. Financial Barriers:	**Evidence:**	**Impact:**
High initial investment cost.	Substantial capital expenditures are required for advanced recycling technologies and hydrometallurgical plants	Prevent investments, particularly when the return on investment is uncertain.

Uncertain Return on Investment	difficulty in predicting the profitability of circular economy technologies	makes it challenging to secure investors' confidence and funding
Market volatility:	fluctuating prices for recycled materials and energy.	create economic uncertainty that can undermine long-term planning and investment.
2. Regulatory Barriers:		
Complex Regulatory Frameworks	navigation complex rules on permit requirements for treatment and recycling	Slow implementation of new technologies and increasing compliance costs
Inconsistent Policy Support	Changes in government policy related to sustainability and waste management	Create uncertainty that makes businesses hesitant to invest in circular practices
Permit Delay	long processing time for obtaining the necessary permits for new technologies	delayed project implementation and increase the overall cost

3. Operational barriers		
Resource Limitation	insufficient financial and human resource institutional focus on sustainable development	Hinders the effective implementation of a circular economy initiative
Insufficient Data	Lack of comprehensive data for informed decision-making about technology integration	limited ability to track progress on measures effectiveness of a circular initiative
Knowledge Gap	A lack of shared understanding between different government ministries about sustainability goals	Slow efforts to integrate technology into circular practice effectively
Public Perception Barrier	public opinion can impact the success of new technologies, particularly those related to waste management and energy production	Can complicate regulatory approval and funding for circular technology

IQ3. How can these challenges be addressed to facilitate a smooth transition to the circular economy?

Finland's path toward a circular economy is more than a promise, but it's almost a reality, with strategic solutions to navigate the identified challenges that currently limit technology integration. Addressing these barriers demands various approaches that combine policy, innovation, financial mechanisms, knowledge development and collaboration within businesses that operate in the circular framework. This research investigation explores solutions that can transform these limitations into opportunities for advancement. This qualitative research analysis identifies some key solutions that are focused towards reducing regulatory complexity and uncertainty for businesses that seek the integration of technology for circular business initiatives, innovative financing mechanisms that distribute risk and reduce capital barriers and creating efficient resource utilisation. By observing the targeted solution below, Finland can accelerate the adoption of circular technologies while creating a favourable environment for innovation to flourish. The strategic combination of these approaches will guide toward a comprehensive framework for facilitating Finland’s easy transition to circular economy practices.

Table of Solutions

Table 3

Policy Regulatory Solutions	**Approach**	**Expected Impacts**
Clear Policy Direction	Consistent, organised policy across the government sector that aligns with practical circular economy implementation needs	Reduce regulatory uncertainty, provide clear guidelines for business

Streamline the Permit Process	Simplifies the permit procedure for circular economy technologies	Reduces delays, lowers barriers to entry of new circular initiatives
Supportive Fiscal Policy	Implement tax incentives, subsidies, and grants for businesses investing in circular economy technologies	Reduce financial burden and encourage the adoption of sustainable practices
financial solutions		
Innovative funding mechanism	Develop specialised financial instruments and investment funds focused on circular economy projects	Improve access to capital for businesses implementing circular technology.
Public-private partnerships	Advances in collaboration between governments and the private sector to share financial risk and resources	Enable a large-scale circular economy initiative that might be too risky for either sector alone
Green Procurement	Use government procurement power to create demand for circular products and services	Establish stable markets for circular economic outputs
knowledge and capacity building		

Enhanced data collection and monitoring	Develop a better system for tracking and assessing the impact of the circular economy	Provide evidence base for decision making and demostratrate the value of a circular approach
Consumer education	Lunch campaigns to raise awareness about the benefits of circular economy products and practices	Stimulate demand for sustainable products and encourage circular behaviours
Cross-sector education	Implement a training program across government ministries, the business sector to build a shared understanding of circular economy practice	Create a coherent approach to circular economy implementation

4.1 Critical Implementation Solution to Findings

Technology integration: Develop a standard system that allows circular technology to be implemented incrementally and integrate with existing industrial processes

Industrial Exchange System: Create a system where waste can be exchanged from one company, becoming resources to another company through a material exchange platform among industries.

Risk distribution: Develop a financial mechanism for a collaborative approach that distributes the risk of implementing new circular technologies

Regulatory Reform: Streamline the regulatory process, basically for circular economy industrial projects, to reduce delay and uncertainty

Knowledge Transfer: Build a training program for an ideas sharing platform, focusing on the practical implementation of circular technologies

4.2 Discussion of Findings

The analysis of this study's findings highlights the essential significance of technical innovation in promoting circular economy practices, especially with Fortum. The findings indicate that Fortum has effectively invested in advanced technologies, including heat pump technology, with a heat recovery system, nuclear power as a CO2-free foundation, gasification technology, pyrolysis system, high temperature incineration with energy recovery, battery recycling technology and carbon capture and utilisation, to improve resource recovery and waste-to-energy operations. This corresponds with current literature, which underscores the importance of these technologies in enhancing material efficiency and mitigating environmental effects (Geissdoerfer et al., 2017).
However, the study emphasises financial and legal obstacles that impede the smooth incorporation of technology into circular economy practices. Significant implementation costs have surfaced as a primary obstacle. Financial strain linked to the acquisition and maintenance of circular economy technology hinders wider adoption. This finding aligns with prior research indicating that the initial capital investment necessary for circular economy innovations frequently prevents businesses, especially small and medium enterprises, from completely adopting sustainable practices (Kirchherr et al., 2018). Additionally, regulatory barriers were also analysed above as a significant obstacle. This research has established that regulatory barriers create uncertainty for enterprises, complicating the alignment of technical investments with long-term sustainability goals (Bocken et al., 2016). This study confirms the premise that financial and legal elements substantially impede the incorporation of technology into circular economy practices in Finland.
A significant theme that arose from this qualitative research is the public perception barriers to circular operations, and customer awareness needs to increase to enable the transition and acceptance of the circular economy. product redesign, process optimisation, and customer education are vital elements of an effective circular economy framework. Previous study indicates that transitioning to a circular economy necessitates fundamental alterations in product design and consumption (Ghisellini et al., 2016). Product redesign aimed at enhancing reusability and recyclability has been recognised as a crucial element in minimising waste generation and augmenting resource efficiency (Ellen MacArthur Foundation, 2017). Moreover, optimising industrial processes to reduce material losses and improve sustainability has been extensively promoted as a viable technique for

facilitating transitions to a circular economy (Merli et al., 2018). Moreover, consumer education has become an essential element, as changes in behaviour towards sustainable consumption patterns are required to stimulate demand for circular economy products and services. Previous research has highlighted the need to enhance awareness about trash reduction, recycling, and sustainable purchasing choices within a comprehensive circular economy framework (Schröder et al., 2019).

The results offer a threefold solution that links business-government-consumers in the integration of technological breakthroughs into circular economy practices. The findings correspond with global trends, demonstrating that although technology innovations present viable solutions for waste management and resource recovery, budgetary limitations and regulatory discrepancies continue to pose substantial challenges. The necessity for comprehensive changes in company and consumer behaviour underlines that the shift to a circular economy demands a multifaceted strategy encompassing regulatory reforms, industry collaboration, and public involvement. These insights highlight the need for specific interventions that tackle financial and regulatory obstacles while encouraging technical advancements and cultivating a culture of sustainability among both enterprises and consumers.

5 Summary and Conclusion

5.1 Summary

This study examines the impact of technical innovation on addressing the obstacles of implementing circular economy (CE) practices, specifically focusing on Finland and the case study company, Fortum. This qualitative research aimed to investigate how technology facilitates the transition to a circular economy, identify obstacles to its integration, and propose methods to overcome these challenges. The study was based on an extensive literature assessment that established a theoretical and empirical framework for comprehending the circular economy, the function of technology, and the obstacles and opportunities related to its implementation.

The literature assessment underscored the tenets of the circular economy, stressing the significance of eliminating waste, maintaining the use of products and resources, and restoring natural systems. The analysis also explored the principal technologies propelling the circular economy, including the Internet of Things (IoT), blockchain, artificial intelligence (AI), enhanced recycling, and waste-to-energy solutions implemented by the case study company Fortum. The research revealed multiple obstacles to the integration of technology within circular economy activities, including financial limitations, regulatory impediments, and behavioural obstacles.

Theoretical case studies from Finland and worldwide have illustrated the capacity of circular economy approaches to enhance sustainability and resource efficiency. Finland's national circular economy roadmap and Fortum's pioneering waste-to-energy technologies were emphasised as exemplars of effective circular economy execution. However, the case studies highlighted the difficulties in expanding circular practices, including the substantial expenses associated with technology adoption and the necessity for regulatory assistance.

The theoretical framework encompassing systems theory, innovation diffusion theory, and the resource-based perspective (RBV) established a solid basis for comprehending the circular economy. These theories highlighted the interdependence of elements within the circular economy, the determinants affecting the implementation of circular practices, and the significance of utilising resources and capacities to attain competitive advantage.

5.2 Conclusion

The shift to a circular economy is essential for attaining global sustainability objectives, since it enhances resource efficiency, minimises waste, and fosters the regeneration of natural systems. Technological advancement is crucial in facilitating this transition by offering creative solutions for maximising resource utilisation, prolonging product lifecycles, and generating value from trash. The incorporation of technology into circular economy activities faces problems such as financial limitations, regulatory obstacles, and behavioural impediments.

Finland has established itself as a global frontrunner in advancing the circular economy, supported by a thorough national plan and pioneering initiatives from companies such as Fortum. Fortum's waste-to-energy solutions and sophisticated recycling technologies exemplify the capacity of technology to promote sustainability and resource efficiency. Achieving a truly circular economy necessitates overcoming the hurdles of elevated costs, regulatory discrepancies, and the imperative for systemic transformations in company practices and customer behaviour.

The theoretical framework encompassing systems theory, innovation diffusion theory, and resource-based view (RBV) offered significant insights into the circular economy, emphasising the interrelatedness of components, the determinants affecting the adoption of circular practices, and the necessity of utilising resources and capabilities. By synthesising these theories, researchers and practitioners can cultivate a holistic comprehension of the circular economy and formulate policies that enhance sustainability, resource efficiency, and economic development.

5.3 Recommendations

This qualitative research proposes the following recommendations to facilitate the transition to a circular economy in Finland:

> **Policy and Regulatory Support:** Governments must formulate laws and regulations that conform to circular economy concepts, including more stringent recycling objectives, prohibitions on single-use plastics, and incentives for sustainable product design. Policymakers ought to standardise regulations across regions and sectors to foster a conducive climate for circular practices.

Collaboration Among Stakeholders: Enterprises, governmental entities, and civil society must cooperate to formulate and execute circular economy initiatives. Public-private collaborations are essential in distributing the financial risks and benefits of circular economy innovations, allowing enterprises to surmount initial cost obstacles and expand their initiatives.

Education and Awareness Initiatives: Governments and enterprises ought to allocate resources to education and create awareness initiatives to advocate for the advantages of circular economy practices and foster sustainable consumption behaviours. Digital technologies, including social media and mobile applications, can facilitate consumer engagement in circular behaviours and foster a culture of sustainability.

Incentives for Sustainable Consumption: Governments and enterprises ought to offer incentives to customers for embracing circular practices, such discounts, awards, or tax deductions for acquiring sustainable items or engaging in recycling initiatives. These incentives can render sustainable alternatives more appealing and economical, prompting consumers to transition from linear to circular purchasing patterns.

Infrastructure Development: Governments ought to allocate resources towards infrastructure development to facilitate circular economy practices, including recycling facilities, sharing economy platforms, and product repair services. This infrastructure facilitates the convenience and accessibility of circular practices, hence diminishing obstacles to adoption.

Integration of Digital Technologies: Enterprises ought to utilise digital technologies, including IoT, blockchain, and AI, to maximise resource utilisation, improve product lifecycle management, and develop innovative business models. These technologies can enhance the efficiency and transparency of circular supply chains, hence rendering the system more resilient to disturbances.

Emphasize Systemic Transformations: Enterprises must embrace a comprehensive strategy for circular economy integration, taking into account the complete lifecycle of products and materials while involving stakeholders throughout the value chain. This method enables firms to recognize opportunities for resource efficiency and waste minimization, generating value from waste and improving their competitive edge.

Investment in Research and Development (R&D): Governments and enterprises ought to allocate resources to R&D to cultivate and expand sophisticated technologies that facilitate circular economy practices, including enhanced recycling, waste-to-energy, and digital platforms. Funding must be targeted for SMEs, who frequently lack the resources to invest in circular economy technologies.

Final Thoughts

The shift to a circular economy is complicated and requires coordinated efforts by governments, enterprises, and consumers. Although technological progress offers the instruments and innovations essential for facilitating circular economy practices, overcoming the obstacles of financial limitations, regulatory obstacles, and systemic transformations necessitates collaboration, investment, and conducive policy frameworks.

Finland's leadership in advancing the circular economy, as illustrated by enterprises like Fortum, illustrates the capacity of technology to enhance sustainability and resource efficiency. Achieving a completely circular economy necessitates a fundamental transformation in resource utilisation and management, alongside a dedication to ongoing innovation.

By implementing the recommendations presented in this study, stakeholders and businesses can realise the complete potential of the circular economy and establish a more sustainable and resilient economic framework. The circular economy serves as a remedy for environmental issues while simultaneously providing a chance to stimulate economic growth, provide employment, and improve quality of life. Immediate action is vital, and the obligation rests with each of us to actualize the circular economy.

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Appendices 1

Secondary Data Utilisation

This appendix outlines the systematic method used in collecting, analysing, and interpreting secondary data for this qualitative research on technological challenges in circular economy implementation.

The research mainly utilised Fortum's sustainability reports (2020-2023) as core documents, supported by academic literature and policy frameworks. All secondary sources were evaluated for credibility, relevance, and currency before inclusion. The analytical framework involved careful reading of technological barriers and enablers, with particular attention to digital transformation initiatives, resource recovery technologies, and system integration challenges.

Content analysis was conducted using a three-stage process: (1) preliminary scanning to identify relevant sections, (2) in-depth reading and analysis (3) cross-comparison between documents to identify patterns. This methodical approach was time-consuming but allowed me to make informed decisions about finding across multiple sources, enhancing validity despite the limitations inherent in secondary data analysis.

The insight gathered from scanning through this document gives valuable knowledge that helps the findings and development of the conceptual framework presented in Chapter 4, providing evidence-based insights into how technological advancements contribute to the integration of circular economy implementation within the energy sector.

Data table

Date	Data type	source	Relevant to study
2019 2020 2021 2022 2023	Sustainability Report	https://www.fortum.fi	Provide relevant information on yearly data that relates to operational dealings, both on sustainability, community development projects, waste recovery and technological innovation, and plans.
2020	Biodiversity Action Plan	https://www.fortum.fi	The Fortum biodiversity manual aimed to improve biodiversity in operations and technology.
2021	Fortum Climate Change	https://www.fortum.fi	This document is used to assess the canon neutrality of their operation, analyse plans for improving renewable energy
2022	Electrification Investment	https://www.fortum.fi	Document to evaluate Fortum infrastructure and industrial electrification

2019	Finland 2030 Sustainability Goal	Article	An evaluation of Finland's sustainable development policy and goal for 2030
2022 2023	CDP Questionnaire	https://www.fortum.fi	Use to provide methodological value of the board's oversight of climate-related issues

Figure 1. Steps in conducting qualitative research with secondary data (Creswell, 2016).

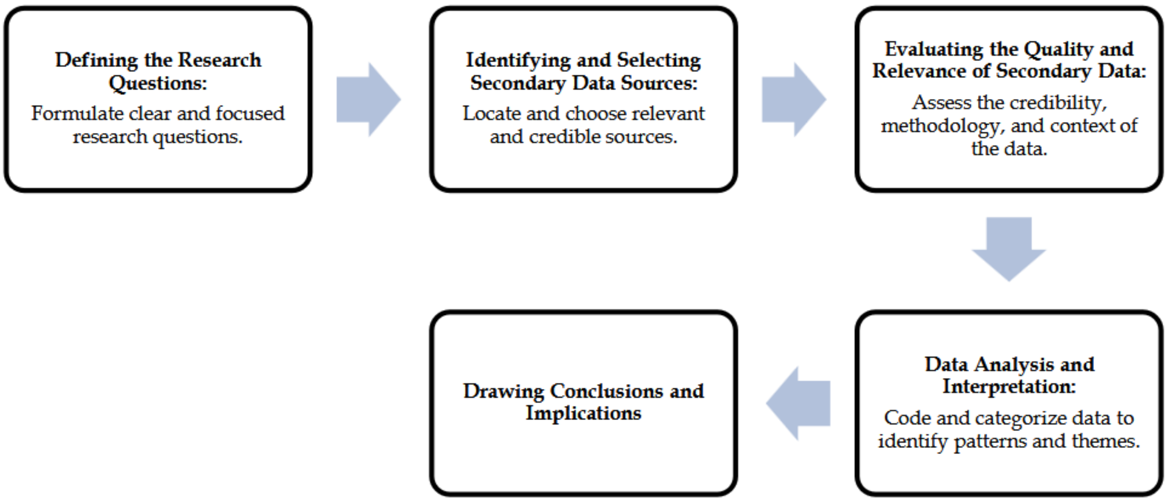

Figure 2: (Fortum sustainability report 2023)

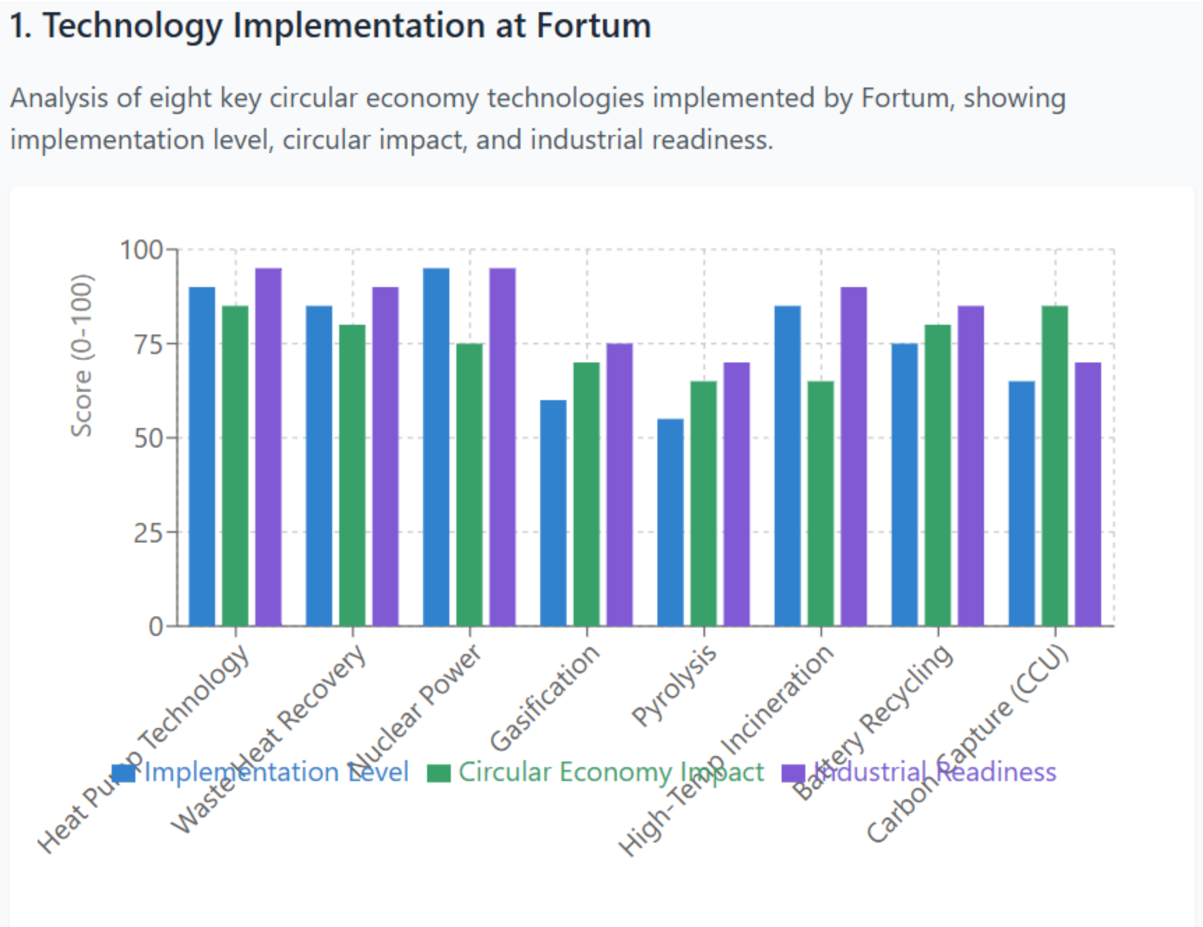

Figure 3: (Fortum sustainability report 2023)