



FACULTY OF TECHNOLOGY

**COMMERCIALIZATION CHALLENGES OF
ADSORBENT MATERIALS FOR WATER AND
WASTEWATER TREATMENT**

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ABSTRACT

Commercialization Challenges of Adsorbent Materials for Water and Wastewater Treatment

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Adsorption is commonly used to remove low-concentration natural organic matter or industrial contaminants from drinking water to improve the water's taste, color, or safety. Adsorption is carried out with adsorbents, which are solid materials. Scientific research on adsorbent materials has increased exponentially, resulting in rapid advancements in preparation methods, chemical modification, and adsorbent quality assurance, revealing remarkable capacities to absorb organic and inorganic pollutants from natural water and industrial wastewater. However, the experimental new adsorbent materials are only seldomly productized and commercialized despite extensive research.

The goal of the thesis was to facilitate the commercialization processes of adsorbent materials for water and wastewater treatment through productization. To achieve the goal, a productization platform for adsorbent materials was first developed through a literature review of business models, productization, and the new technology introduction. The second step was to perform qualitative research. Companies in Finland that represent adsorbent materials producers and vendors, consultants providing water treatment design services, and end-users of adsorbent materials were interviewed for the empirical research. The assessments of the opportunities and challenges in the adsorbent materials productization are based on the analysis of the current status of the interviewed companies. Finally, the research results and the concept of the literature review were

combined to recommend a reference business model and productization structure of adsorbent materials for water and wastewater treatment.

Clarifying offerings and building a business strategy to support the commercialization of the offering are the two aspects of the productization platform for adsorbent materials. The empirical results led to a determination of the water and wastewater treatment requirements and customer expectations. Materials, legislation and standards, cost, customer, and logistics were listed as the five most important water and wastewater treatment requirements, followed by a long list of consumers (companies with water and wastewater treatment plants) expectations (adsorbent materials should be legally proven, tested, validated, cost-effective, previously used for the same purpose, marketed, etc.). These requirements and expectations indicate that an adsorbent materials manufacturer, distributor, and service provider should have compelling business models. A business model assists in integrating needs and expectations into the product application by understanding and linking the product's commercial and technical structure, which results in a commercially successful product. As a result, even though companies face numerous challenges, the productization of adsorbent materials offers innumerable opportunities.

Conclusively, a constructive and descriptive business model, as well as a productization framework, were recommended. An effective business plan and perfect productization of the adsorbent materials can aid in commercializing novel adsorbent materials. "The offerings (adsorbent materials) can be offered as - adsorbent materials as a product-oriented and adsorbent materials as a result-oriented," was the key recommendation for commercializing novel adsorbent materials.

Keywords: Business Models, Productization, Product structure, Commercialization

FOREWORDS

This master's thesis focuses on adsorbent materials for water and wastewater treatment. Its business models, productization concept, and new technology/product introduction are analyzed from an industry perspective using a literature review and empirical research. This master's thesis was done as part of the master's degree program in Industrial Engineering and Management at the University of Oulu's Faculty of Technology. The research began in November 2021 and was completed in May 2022.

To my supervisors Associate Prof. Jukka Majava, Assistant Prof. Tero Luukkonen, and Prof. Harri Haapasalo. I like to express my gratitude to them for their valuable advice and suggestions, which have always compelled me to do my best. I consider myself extremely fortunate to be working under their supervision.

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Oulu, 05.05.2022

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TABLE OF CONTENTS

ABSTRACT

FOREWORDS

TABLE OF CONTENTS

1 INTRODUCTION.....	7
1.1 Background	7
1.2 Objectives	8
1.3 Research Process and Structure of the Thesis	9
2 LITERATURE REVIEW	11
2.1 Business Models.....	11
2.1.1 Business Model Framework	12
2.1.2 Business Model Canvas	13
2.2 Productization.....	14
2.2.1 Benefits and Drivers of Productization.....	15
2.2.2 Challenges of Productization.....	16
2.2.3 Presentation of Product Structure	17
2.2.4 Vertical and Horizontal Productization	20
2.3 New Technology Introduction	21
2.3.1 Technology Life Cycles.....	22
2.3.2 Barriers of Technology Commercialization	23
2.4 Literature Synthesis	24
3 EMPIRICAL STUDY	29
3.1 Research Method and Process	29
3.1.1 Research Design	30
3.1.2 Data Sources	31
3.1.3 Data Collection and Analysis	33
3.2 Adsorbent Materials Overview	33
3.2.1 Applications and Market Size.....	35
3.3 Current State Analysis of the Case Companies.....	37
3.3.1 Water and Wastewater Treatment Consultancy and Process Design	37
3.3.2 Companies Producing and Distributing Adsorbent Materials	43
3.3.3 Companies with Water and Wastewater Treatment Plants.....	47
3.4 Water and Wastewater Treatment Requirements	50
3.4.1 Material Requirements.....	50

3.4.2 Legislation and Standards Requirements.....	51
3.4.3 Cost Requirements.....	51
3.4.4 Customer Requirements.....	52
3.4.5 Logistics Requirements.....	52
3.5 Customer's Expectations from Producers and Service Providers.....	52
3.6 Producers and Service Provider's Expectations from Customers.....	53
3.7 Synthesis of the Empirical Findings.....	54
4 DISCUSSION AND RECOMMENDATIONS.....	60
4.1 Business Model Framework.....	60
4.2 Productization Framework.....	62
5 CONCLUSION.....	69
5.1 Main Contribution of the Research.....	69
5.2 Evaluation of the Research.....	71
5.3 Future Research.....	72
REFERENCES.....	73
APPENDIX.....	81
Appendix 1. Interview questionnaire	

1 INTRODUCTION

1.1 Background

New technology and innovative products are strong foundations of a successful corporation (Simula et al. 2008) that provide the enterprise with extremely high returns when risks are considered and innovations are implemented (Iyer et al. 2006). Creating new strategies for products or services to increase sales and build a brand by utilizing evolving technologies, new methodologies, and doing the right thing at the right time can result in new business and success for the organization. It is critical to continue innovating and discovering better ways to enhance operating modes to keep a firm developing and booming. New technologies and innovations can be game-changers for the organization if thoroughly examined its goals and plans regarding costs, benefits, and alignment. Productization and commercialization broaden the idea of product development to include a significant commercial and design component in addition to technological development efforts (Suominen et al. 2009).

Adsorption plays a vital role in environmental engineering because of its capability in handling a wide range of pollutants and ease of operation (Busetty 2019). Adsorption allows the removal of contaminants from a gas or liquid stream while also contributing to waste minimization, restoration, and recovery by emphasizing adsorbent properties and adsorption capacities (Gisi et al. 2016). Due to increased industrialization and urbanization, wastewater production and treatment have become a growing concern in the twenty-first century. The employment of various treatment strategies (physical, biological, and chemical) may result in the production of secondary pollutants. So, to avoid or minimize the formation of secondary pollutants, one of the strategies is to use adsorbent materials for water and wastewater treatment (Younas et al. 2021). In recent decades, scientific research and subsequently the number of scientific publications on adsorbent materials have expanded exponentially, resulting in rapid advances in preparation methods, chemical modification, and adsorbent quality assurance, revealing remarkable capacities to absorb organic and inorganic pollutants from natural water and industrial waste (Mudhoo et al. 2021). Despite the massive research activities, large majority of the novel adsorbent materials are not productized and commercialized.

1.2 Objectives

This research aims to analyze the commercialization challenges of adsorbent materials to determine the optimal model, strategies, and approaches for productizing adsorbent materials. This research focuses on adsorbent materials for water and wastewater treatment. To be more specific, the scope encompasses various aspects of productization difficulties, drivers, and barriers. The thesis will answer the following research questions to accomplish the thesis's objectives.

RQ-1 How can adsorbent materials for water and wastewater treatment be analyzed for productization?

The first research objective aims to understand the adsorbent materials business environment and create a productization platform for water and wastewater treatment adsorbent materials based on a review of the literature. The goal is to develop a platform that first clarifies the offering, which is then transferred to the company's business strategy to design standard commercial and technical product structures to productize adsorbent materials. This shows a business model serving as the foundation for the productization logic.

RQ-2 What are the opportunities and challenges in the adsorbent materials productization?

The second objective is to conduct empirical research to analyze the business model, new technology/product introduction, and productization concept of the case companies. As we all know, identifying customers, requirements, and expectations is a prerequisite for productization. The primary goal is to identify the customers and then investigate water and wastewater treatment requirements and expectations of customers, producers, and service providers based on the information provided by interviewees. The empirical results open up the opportunities while having several challenges during the productization of the adsorbent materials.

RQ-3 How should adsorbent materials for water and wastewater treatment be productized to advance commercialization?

The third objective of this research is to carry out a discussion of the literature review and empirical findings and recommend a constructive and descriptive business model and productization framework to advance the commercialization of novel adsorbent materials. The goal is to create the business model that will serve as the foundation for the productization logic. In contrast, productization will simplify and justify the firm's offers to make them commercially ready.

1.3 Research Process and Structure of the Thesis

This research on adsorbent materials for water and wastewater treatment commercialization challenges is focused primarily on identifying and analyzing the drivers and barriers to the productization and commercialization of adsorbent materials. The research reviewed the available scientific literature on the business model, productization, and new technology introduction. The scientific literature was explored to better understand the fundamental theoretical approaches relevant to this thesis. Journal articles related to the topic of this thesis were identified using Google Scholar, Science Direct, ResearchGate, and the University of Oulu Library database. The general concepts have been condensed to comprehensively understand how a business model and the introduction of new technologies may be coupled to create a productization approach. Following the theoretical synthesis, the generic information, market size, and applications of adsorbent materials were discussed. In addition, the most commonly used adsorbent materials for water and wastewater treatment were studied and presented, as well as the methodology employed to achieve the above objectives.

For this research project, a qualitative technique was chosen since it focuses on creating knowledge of the issue rather than analytically demonstrating or disproving a particular statement. So, the thesis is descriptive and based on a literature review and qualitative empirical research (interviews with the case companies). The literature and interviews with the case companies address all the research questions. As shown in figure 1, the thesis's objectives are accomplished after answering the research questions. The research logic is divided into three steps, as represented by the research questions. The literature review will provide an answer to the first research question. The second step is to go over the empirical research findings and results to answer the second research question. On the other hand, the third research question will be addressed by making recommendations in the adsorbent materials industry.

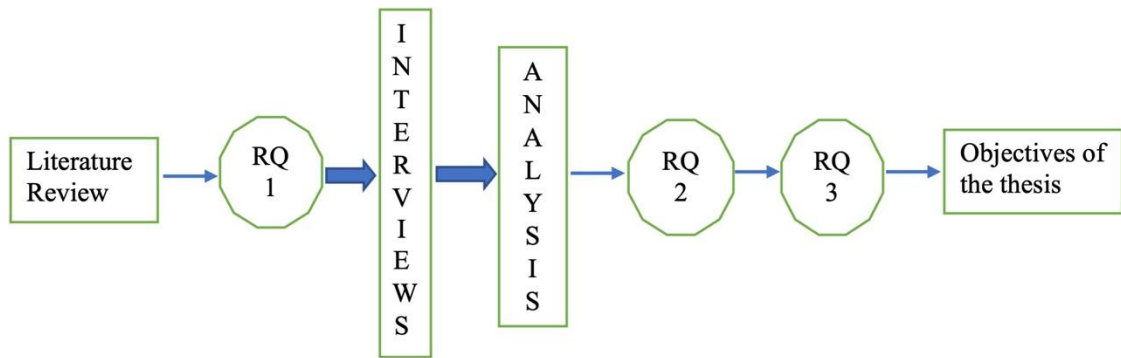


Figure 1. Research process.

The study is structured into five chapters, each with a different focus. The focus of each chapter is as described below:

Chapter 1 – The research's background is described in the first chapter. This section outlines the research questions, scope, and the research process.

Chapter 2 – This chapter provides the theoretical foundation for the thesis's topic. The literature review focuses on business model terminology, productization, and the introduction of new technology.

Chapter 3 – The second part of the research is the empirical research to analyze the business model, new technology/product introduction, and productization concept of the case companies to determine the drivers and barriers of adsorbent materials for water and wastewater treatment productization.

Chapter 4 – This chapter discusses the literature study and empirical findings and proposes recommendations to help commercialize adsorbent materials for water and wastewater treatment.

Chapter 5 – This chapter summarizes the thesis' findings and recommendations. In addition, evaluate the thesis and suggestions for future research topics.

2 LITERATURE REVIEW

2.1 Business Models

To comprehend the concept of a “Business Model,” we must first understand the definitions of the two terms: “business” and “model.” According to Osterwalder et al. (2005, p. 2) ‘business’ is “*the activity of providing goods and services involving financial, commercial, and industrial aspects,*” and ‘model’ is “*a simplified description and representation of a complex entity or process.*” Al-Debi et al. (2008, p. 8) presented a summary of all the available definitions of the business model in one “*The business model is an abstract representation of an organization, be it conceptual, textual, and/or graphical, of all core interrelated architectural, co-operational, and financial arrangements designed and developed by an organization presently and in the future, as well as core products and/or services the organization, offers or will offer, based on these arrangements that are needed to achieve its strategic goals and objectives.*” The business model concept is what customers need, how they choose it, and how well the company may structure itself to provide those demands best, be paid, and profit (Teece 2010).

Lambert (2008) proposed basic and comprehensive business models that concentrate on specific aspects, such as value-adding procedures, resources availability and offers, and value propositions. The Basic Business Model outlines how an entity interacts with all other entities in the value arena, value transfers, and value creation activities. The process Viewpoint, also known as the Comprehensive Business Model, displays the elements of the product offering the value-adding activities (Lambert 2008). The essence of business operations is represented by business models, which assist management in methodically examining success determinants and changing their commercial actions. By simplifying the complexities and dynamism of the modern business environment, business model management assists firms in developing new business concepts, examining existing company activities, and modifying their strategies and structures (Wirtz 2020). Casadesus-Masanell et al. (2011) stated that a successful business model includes choices and consequences and has three qualities:

- Connected with the organization's aims - The decisions taken when creating a business model have implications that help an organization achieve its objectives.

- Self-reinforcing - The executives' selections complement one another while developing a company model, resulting in internal consistency.
- Robust - A good business model maintains its efficacy over time by fending-off challenges.

2.1.1 Business Model Framework

Lambert (2008) developed a business model framework to argue that a conceptual framework will provide a structure for business model concept growth by providing a framework through which researchers can discuss, acknowledge areas of agreement and conflict, and identify possible points of connectivity or linkage, as well as future research areas. Table 1 shows the level of the business model conceptual framework and its details.

Table 1. Level of Business Model Conceptual Framework [modified from (Lambert 2008)].

Level	Business Model Conceptual Framework	Details
1	Definition of Business Modelling	It provides users with insights into the functional requirements that drive the institution's existence.
2	Objectives of Business Modelling	To provide users with explicit knowledge of the business logic that supports the entity's presence and the technology needed to put the business concept into action.
3	Fundamentals	- Characteristics of business model representations on a qualitative level. - Business Model Elements
4	Operational	- Basis of recognition - Basis of measurement - Measurement techniques
5	Business Model Representations	- Basic Business Model - Comprehensive Business Model

Suikki et al. (2006) introduce two business model frameworks: one for defining and constructing business models and the other for analyzing business concepts in the mobile telecommunications industry. Still, the fundamental idea applies to other sectors. The business model elements are grouped into three categories in the framework: offering, value creation, and revenue model. On offer, a business should research what they deliver to clients, who the customers are, and how sales generate capital into the business. When it comes to value creation, the organization should define who the participants, investors,

suppliers, and buyers are about the primary business of the offering. The third aspect is the revenue model, which describes the profit channels, pricing structure, market data, and share of the overall value generated in the network (Suikki et al. 2006). Table 2 displays the dimensions for describing, constructing, and assessing the business model, as well as the components that businesses should consider.

Table 2. Framework for describing, building, and evaluating business models [modified from (Suikki et al. 2006)].

Dimension for describing and building framework	Component	Dimension for evaluation framework
Offering	Composition	Suitability Internal consistency
	Customer	
	Sales approach	
Value creation system	Structure	Uniqueness Efficiency Ability to capture value
	Network players	
	Network size	
Revenue model	Basic logic	Economic considerations Future potential Feasibility
	Cost and pricing structure	
	Market	
	Share of the total value	

MacInnes (2005) proposed a new framework for business models in the case of emerging technologies, identifying four stages: factors to overcome technical difficulties, factors to overcome environmental issues, factors to overcome business model barriers, and factors to overcome at maturity. Developers of new technology tend to evaluate the hurdles to build sustainable business models after first focusing on technical and then environmental issues. At this stage of maturity, the business model should consider aspects that will help the company stay afloat as it grows (MacInnes 2005).

2.1.2 Business Model Canvas

According to Osterwalder and Pigneur (2010), a business model can be best characterized through nine key building elements (as shown in figure 2) that demonstrate the logic of how a company aims to generate revenue / profit. Customers, offers, infrastructure, and

financial sustainability are the four fundamental components of a business covered by the nine blocks. The business model serves as a blueprint for implementing a strategy through organizational structures, procedures, and systems. A business model approach should be simple to grasp, allowing for easy explanation and discussion when considering one's own company and competitors. A business model canvas converts the business strategy into business operations, encourages teams to think about the business strategically, and prevents becoming bogged down in the technicalities. (Osterwalder and Pigneur 2010). According to Teece (2010), a business model must be more than just an excellent reasonable way of conducting business that must be tuned to satisfy specific client needs to be a critical success factor.

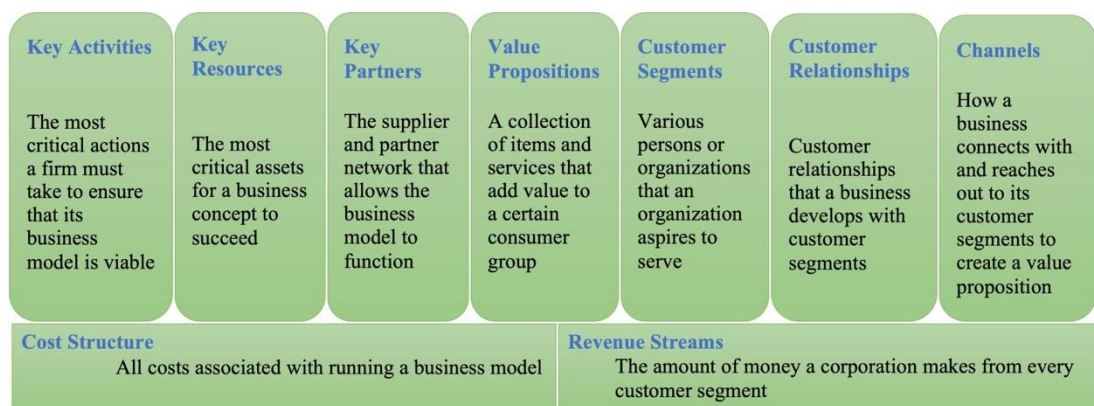


Figure 2. Business Model Canvas [Modified from (Osterwalder and Pigneur 2010)].

2.2 Productization

To comprehend the concept of 'Productization,' it is necessary first to understand the definitions of 'product' and 'strategy.' Baker and Hart (2007) defined a product as "Anything produced for sale, especially something made through an industrial process or something cultivated or reared through farming" and strategy as "a long-term plan for doing something or obtaining a goal, or the ability to organize well." In simple understanding, productization is a combination between products and the best strategy to sell the product. Productization is the act of examining a need, identifying, and merging appropriate pieces into a repeatable and understandable brand item. Commercial readiness activities enable selling, delivering, using, and invoicing. In services, productization tackles the often abstract and intangible objects of exchange. It is essential

to explain the service provided, ensure replicability, and improve understanding (Harkonen et al. 2015).

Standardizing processes and products to replicate items or services with the same resources and results is critical for productization definitions. Another crucial aspect is comprehending the company's offerings and the resources required by each element. This means that there are no significant disparities in the literature and understanding of the business concept of productization. Productization is frequently separated into product, service, software, and technology productization. Product productization is the most widely discussed topic, followed by the productization of services (Harkonen et al. 2015). Productization is perceived as a predictable process involving a series of carefully planned and well-organized stages that reduce the time spent on traditional product sales and marketing, understanding customer needs, and developing a commercial strategy that addresses those needs while making a profit (Hämnen et al. 2012).

2.2.1 Benefits and Drivers of Productization

During product development, companies and their manufacturing processes face ambiguities and difficulties internally (within the company) and externally (within the market). Hence, productization benefits to reduce those internal and external challenges and help sell the products. The major drivers and benefits for productization initiatives, according to analyses of significant publications in productization methods and methodologies, are:

- Specification, Standardization, Systemization, and Expertization of the product or services to make them identical (Jaakkola 2011; Wirtz et al. 2021)
- Standing out in a competitive marketplace, conducting market research, and upgrading offerings to meet changing client needs (Valminen and Toivonen 2007; Simula et al. 2008)
- ensures the quality of a core product, as well as outbound operations that result in the creation of an extended product (Simula et al. 2008; Jaakkola 2011)
- Customer satisfaction, the ability to improve the value provided to customers, and potential repercussions on environmental, social, and economic sustainability (Elia et al. 2019)

- Increasing the performance of engineering-oriented development to deliver innovations by increasing the link between market needs and technology development (Valminen and Toivonen 2007; Harkonen et al. 2015)

The primary motivation for implementing productization is to improve the competitiveness and cost-effectiveness of services or products. The need for productization differs depending on the company's perspective on competition identification. Productization's most visible effect makes a service or product more physical, systemized, and standardized. (Valminen and Toivonen 2007)

Productization formalizes the offering and explains processes to decrease overlapping effort and improve service quality. Internally, productization begins when the company's internal procedures are inefficient. Productization creates the core structure for services and eliminates the need to reinvent every customer to increase manageability and customer happiness. Productization's defining, standardizing, systematizing, and tangibilizing features make it more profitable, efficient, and competitive to attain customer satisfaction through value-added products. (Jaakkola 2011; Harkonen et al. 2017; Harkonen 2021)

2.2.2 Challenges of Productization

Companies and their manufacturing processes face difficulties in producing and marketing their products. Confusions and challenges grow when comprehending and describing the essential functions and demands within the organization and with clients (Harkonen et al. 2015). One of the most challenging elements is making decisions on developing a dependable and logical productization solution and managing the solution offered throughout its existence, followed by reasonable accuracy and availability of information challenge, both resulting in using and conveying inaccurate data and information (Hänninen et al. 2012). Poor commercial productization lacks clarity about what is sold to clients and the various possibilities. In contrast, poor technical productization led to an overflow of technological diversification (Mustonen 2020). Even though practitioners and industrial professionals frequently use the term "productization," describing and understanding complex products, services, software, or technology is always a challenge because the productization concept is not well-established in the scientific literature (Harkonen et al. 2015). Furthermore, some common challenges in

companies are constantly increasing products and having vast product portfolios (Mustonen 2020), a lack of product portfolio thinking skills, a little concentration on new product development, a disrespect for lifecycle thinking, and regular portfolio renewal (Tolonen et al. 2014a), the failure to evaluate things structurally, especially commercially, indeed produces problems (Harkonen et al. 2019), and last but not least varying productization approaches and definitions among organizations make comparing their offerings difficult (Mustonen 2020).

2.2.3 Presentation of Product Structure

A product structure consists of components (assemblies), the externally visible characteristics of those assemblies (sub-assemblies), and the relationships that form a hierarchical structure (Crnkovic et al. 2003). Through a standard product structure that recognizes both commercial and technical perspectives, productization could be used to present and project products and put them into a similar systematic and repeatable format, as shown in figure 3. The generic product architecture encapsulates all the product's numerous capabilities in a single description, wherein the final customer-specific configuration is formed, assisting in formalizing the company's distinct goods and their understanding at multiple levels (Kropsu-Vehkapera and Haapasalo 2011). According to ElMaraghy et al. (2013), having a large number of product variations is not always a good thing; it might confuse customers and result in inexpensive costs for the organization (for example, in terms of product development, production, distribution, sales, and after-sales services). Product structural logic defines the offering by specifying what can be developed, advertised, sold, and delivered. The profitability of each option can be increased by connecting the commercial and technical sides of the product structure, analysis, and judgments on the total offering. (Mustonen et al. 2019; Lahtinen et al. 2021). To ensure a completely functional product, two elements are required: a) Product structure management; b) assuring the deployment of supporting functionalities throughout the lifespan. Product structure helps to organize data by giving a hierarchy to define the breakdown of a product. Productization begins with the commercial and technical analysis of products using the product structure concept, which may be a key to product profitability throughout its existence (Tolonen et al. 2014; Mustonen et al. 2019; Lahtinen et al. 2021).

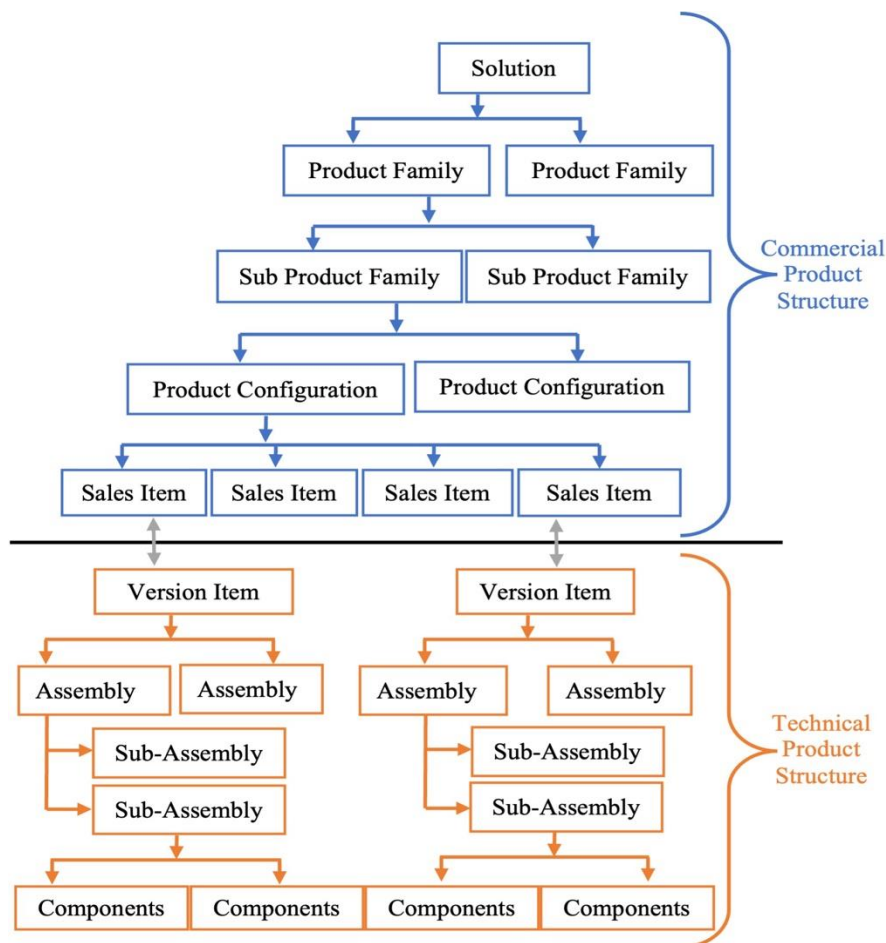


Figure 3. Product Structure [combined and modified from (Tolonen et al. 2014; Mustonen et al. 2019)].

A reliable product structure allows for more effective identification of products and their constituent components as data in firm IT systems and better management of the product portfolio throughout its lifecycle (Lahtinen et al. 2021). To maximize effectiveness, the product structure concept can be applied to product portfolio management, which is concerned with the requirement to monitor and react to the behavior of products and services both in the marketplace and within the firm (Cooper et al. 1997; Tolonen, Harkonen, et al. 2014). The product structure should accept or admit the existence of productization because it deals with the commercial and technical aspects of the items (Harkonen et al. 2017).

Commercial Product Structure

Product families, product configuration, and selling items are forms of products that can be sold to customers make up the commercial side of the product structure hierarchy. As

a result, any changeable features and functions that the consumer might select should be viewed as different things on the commercial side (Mustonen et al. 2019). It is feasible to determine where the company's sales turnover comes from by looking at its commercial portfolio. The company's sales, marketing (Mustonen et al. 2019), and product management departments are primarily concerned with commercial matters, which means that controlling a commercial portfolio entails expenses. Customers can see the commercial portfolio and its adjustments to recognize the company itself (Tolonen et al. 2014b).

Depending on the organization's size and needs, the commercial side may have multiple levels of hierarchy that are visible to the buyer. In the product structure, the solution level is the highest. It can be a mix of product families, configurations of distinct product structure branches, or even single sales products. A product family is a group of product configurations targeted at the same clients or using the same technology platform. Product configuration combines predesigned sales components to produce new products that meet specific customer needs. The lowest level of the commercial side is sales products, which can be sold, delivered, and billed. Hardware, software, services, and documentation are all examples of sales items (Lahtinen et al. 2021).

Technical Product Structure

The technical side of the portfolio is where the most significant variation in the productization of physical products and services can be found. The technical structure of a physical product consists of assemblies, subassemblies, and components, whereas the technology structure of service consists of service processes, subprocesses, and tasks (Mustonen et al. 2019). Product development, production, testing, procurement, logistics, and subcontracting all look into the technical side of the organization. In addition to the sales and marketing departments, product management departments, and the commercial portfolio, the technical portfolio can determine the company's cost structure. The corporation can identify ways to cut manufacturing costs and offer new products by analyzing and altering the technology portfolio (Tolonen et al. 2014b).

When a feature of the original product is upgraded, version items are developed. Typically, these improvements involve cost reduction or increased quality or performance. The main assembly is the highest degree of assembly from a manufacturing

standpoint. Subassemblies, the lower tier of groups, include the essential components from which the product is produced and used to make main assemblies. The component level is the lowest in the product hierarchy. On the technical side, product modularity is essential. The nature of the product determines how the technical side is described (Lahtinen et al. 2021).

2.2.4 Vertical and Horizontal Productization

As we know, Productization is the process of defining a company's products to establish a uniform understanding of the company's product offering, and product structure defines the offering by specifying what can be developed, advertised, sold, and delivered. Hence, it can be understood that productization is linked to product structure to describe the life cycle stages of the product development and commercial and technical aspects of the product.

Vertical productization is the process of expressing the commercial and technical aspects of a product through a product structure that highlights both the sellable and technical aspects of the product line. Horizontal productization refers to categorizing products based on their lifecycle stages to better grasp the marketable and deliverable proposition at various product lifecycle stages (Mustonen 2020). As shown in figure 4, Vertical productization characterizes commercial and technical product structures wherein solution, product family, product configuration, and sales item portfolios contain marketable products. The main assembly, sub-assembly, and component portfolios have non-sellable technical products. In horizontal productization, the product and product portfolio lifecycles are divided into four NPD phases: research and development, maintain, warranty, and archive. New sellable or technical items are developed in the research and development phase, based on entirely new platforms and technologies; in the maintain phase, marketable products are not produced, but existing features are enhanced to the competitiveness of current items by customizing internal technical things; the warranty phase focuses on aftersales services (spare parts and support services); and finally, the products are archived in the short or long term, depending on the circumstances (Tolonen et al. 2015). The vertical and horizontal productization aspects will also be used in product portfolio management, aiming to make product decisions if you have a clear and up-to-date understanding of the company's independent product portfolios (Mustonen 2020).

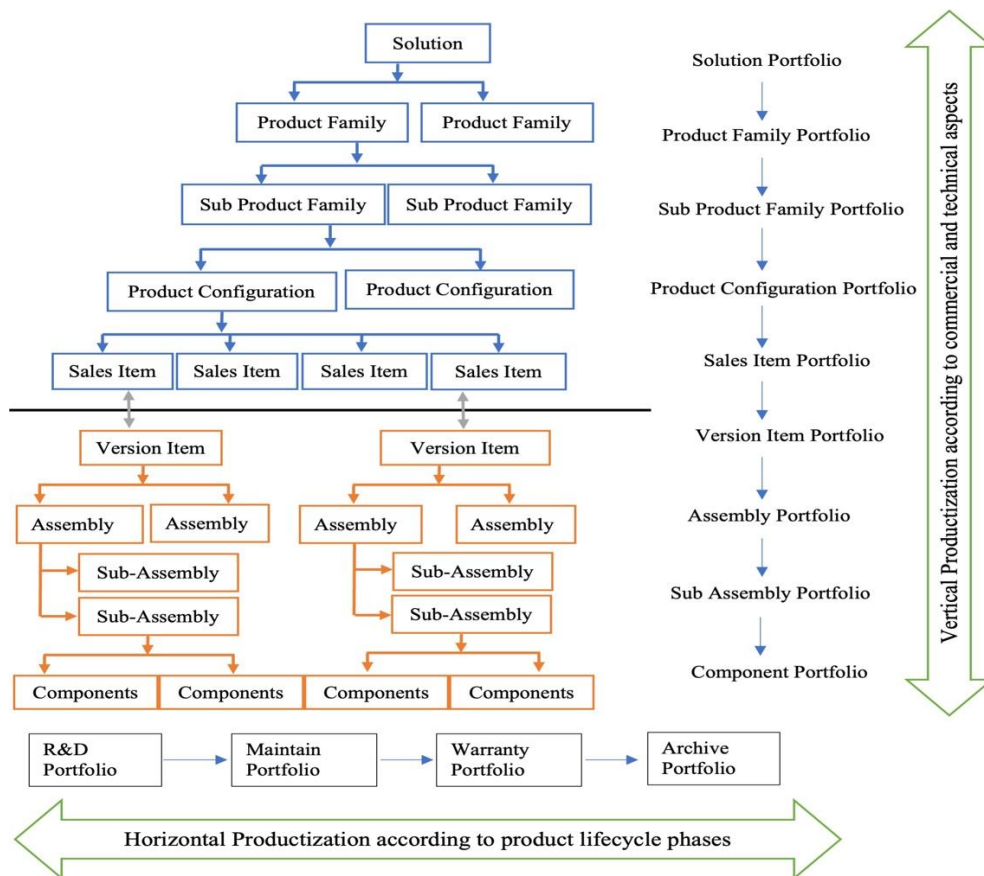


Figure 4. The vertical and horizontal productization dimensions framework [(Tolonen et al. 2015)].

2.3 New Technology Introduction

Dodgson et al. (2008) state that technology is a repeatable item with a practical application expressed through new goods, processes, and systems requiring knowledge and capabilities to develop and operate it to deliver repeatable operations. Khalil (2000) classified technology as new, emerging, high, low, medium, appropriate, and codified versus tacit technology. Knowledge and capabilities are two distinct types of information that can be encoded in a physical artifact like a machine, component, system, or product. So, one of the essential qualities of technology is that it is applied and focused on an organization's "know-how" (Phaal et al. 2001). New technology is a method of refining old technology and establishing new things that aid in achieving the benefits and likelihood of overall progress. Usually, improving old technology or developing new technology for valuable advancements is challenging and often difficult to forecast (Haapasalo et al. 2008).

Innovation is the gateway to new technology. According to Dodgson et al. (2008), Innovation entails the scientific, technological, organizational, financial, and business efforts that lead to launching a new (or enhanced) product or service for effective commercial exploitation. The innovation systems approach to economic development is considered particularly useful from a dynamic perspective. It can explain and anticipate the rise and fall of growth companions such as financial and social development, institutions, and technology. (Niosi 2008).

The impact of new technology on management, organization, and work is becoming more empirically documented. Most of the focus has been on either the 'impacts' of new technology or the societal choices and decisions that underpin management strategies for its deployment. New technology can both endanger and create new opportunities for users. The implementation of plans for the effective launch can be designed based on responses to specific product markets and the availability of new technologies (McLoughlin et al. 1985). "Most of the technologies will be replaced, and most efforts to replace them will fail," according to Matthews (1991). The statement demonstrated that existing technologies are constantly being replaced or modified for new technologies to be introduced. As a result, every technology has a beginning, a life, and an end. This implies that technology has a life cycle. (Haapasalo et al. 2008)

2.3.1 Technology Life Cycles

The technology life cycle is how a technology's performance is measured in a specific pattern throughout time. A thorough understanding of the technology's life cycle patterns can be instrumental in product development, process improvement, and strategic planning (Khalil 2000). By taking the appropriate measures in the proper life-cycle stages, technology life cycles can help us better comprehend the movements of technologies and the implications of technological breakthroughs to monitor technical advancements (Shahmarichatghieh et al. 2017). The Technology Life Cycle depicts the cumulative product development projects of a technology or its performance over time, indicating the technology maturity level at different points in time (Rizki et al. 2015).

Khalil (2000) presented one of the most often used technology life-cycle models as technology performance patterns with four phases: embryonic, growth, maturity, and aging, referred to as the s-curve of technological progress. Even though Khalil's model

is a widely used technology life-cycle model, several studies criticize it for lacking performance characteristics to depict economic and technical trends. Shahmarichatghieh et al. (2016) investigated seven technology lifecycle models from distinct angles to simplify technology maturity evaluation. Different technology life cycles exist, each with stages for specific aspects. Table 3 is a summary of (Shahmarichatghieh et al. 2016) findings.

Table 3. Summary of Technology Lifecycle [(Shahmarichatghieh et al. 2016)].

Models	Major Aspects	References
First Model	It is based on technology performance patterns, the most generic technology life cycle.	Khalil 2000
Second Model	It is built on four stages of strategic innovation and business planning: embryonic, pacing technology, critical technology, and basic technology.	Little 1981
Third Model	The model uses three stages to track the trends of inventive operations throughout time: performance maximization, sales maximization, and cost minimization.	Abernathy and Utterback 1978
Fourth Model	The model identifies prospects from the viewpoint of the original manufacturer, as well as from the perspective of the technology owner.	Ford and Ryan 1981
Fifth Model	From the product design and creation viewpoint, the model created a technological cycle based on sociocultural aspects.	Anderson and Tushman 1990
Sixth Model	The model is a diffusion model used to predict the rate at which new technology penetrates markets.	Rogers 2010
Seventh Model	The model depicts several technological scenarios in the market and provides recommendations for effective product development methods.	Moore 2004

2.3.2 Barriers of Technology Commercialization

According to Krishnan (2013), Technology commercialization translates technological capabilities into profitable and socially beneficial products and services. It comprises sourcing technology, creating value for competitive products and services, and introducing these offers into the markets. Technology commercialization is a standard technique for staying competitive globally; this does not imply that technologies, products, and services will be successful; however, it must be an integral part of the development and commercialization process (Fratini et al. 2012). Many commercialized products fail due to various limits and problems associated with commercialization.

Most businesses spend truly little money on research and development, yet they always have big expansion plans. The primary impediments to technology commercialization are a lack of understanding about the growing market, market share increases, emerging markets, and acquisitions (Cooper 2011). External barriers (which firms cannot affect and may develop due to demand, government, or economic actors or system faults) and internal barriers (which companies can control and are strongly related to management and the organization itself) are the primary barriers. As a result, weaknesses in the commercialization process, business environment challenges, weak organizational structure, inefficient project management, ineffective collaboration with non-governmental sectors, failure to collaborate with stakeholders, and conflicting political behaviors have been identified as the main challenges of technology commercialization (Khalil Zadeh et al. 2017). Hueske and Guenther (2015) proposed the EOGI barrier model. They classified it as “external environment (external stakeholders: investor, potential employee, supplier, competitor, customer, state, society), organization (managerial levers of dynamic capabilities: strategy, structure, size, resources, organizational learning, organizational culture), group (team structure, team climate, team processes, membership composition based on characteristics, leadership style), and individual (managers' attitudes and abilities, employees' attitudes and abilities).” Most companies face mature markets, tough competition, commoditization, and shareholder demands for short-term profits due to missing innovative initiatives. These factors directly impact the company's managerial, financial, technological, and policy-related functions and act as roadblocks to technology commercialization (Cooper 2011; Meijer et al. 2019).

2.4 Literature Synthesis

According to the literature review, an offering might be a product, service, or technology that should be described commercially and technically structured before being sold, delivered, and billed. The company or companies must create their business models to determine how they will do business and survive the competition. With the introduction of available technology, these can be accomplished. Depending on organizational structure, revenue sources, or product architecture, the business model can be seen in various ways. The business model concept is inextricably tied to a company's ability to produce value for consumers, its internal strategy and organization, and its external

network. However, priorities are revenue generation, its manuscript, and its primary business.

Technology frequently demonstrates itself in various products that specify and add value to clients. However, simply producing a product does not always imply meeting all customer requirements. As a result, to create an enhanced product that a client can understand and is the full version of an offered service or product, a company must perform comprehensive activities other than the construction of the core product. (Simula et al. 2008). Productization of business models allows experiences and knowledge from areas like new product introduction, development, and startup to be applied to business and model transformation processes, resulting in a dynamic relationship between product creators and consumers (Tell 2020).

Business Model Canvas is a strategy implementation tool that allows users to identify and express a business idea or concept by mapping, designing, and discussing new business concepts rapidly and efficiently. Figure 5 is the big picture that shows the business model canvas is linked to the product structure, product lifecycle, and productization to identify the business activity and design of the company and product that adds value to the direct and end-users. The business model partners with product structure and productization activities to create value and determine its structure concerning revenue streams.

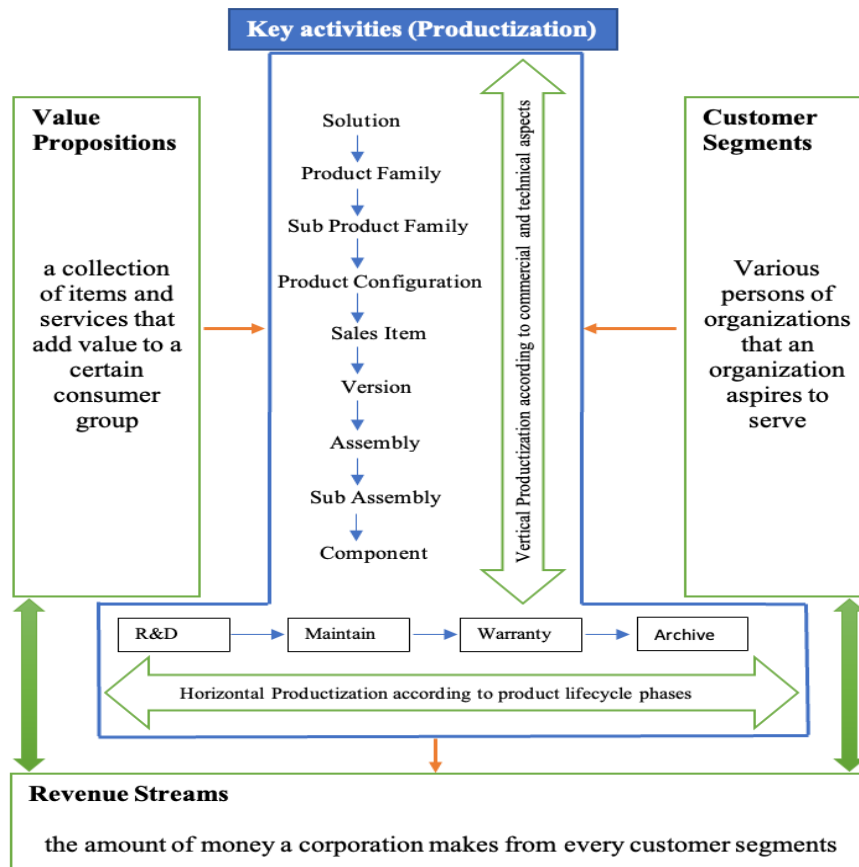


Figure 5. Literature synthesis of business model canvas over product structure, product lifecycle, and productization concept.

The following guidelines will help understand the adsorbent materials business environment and design a productization platform for water and wastewater treatment adsorbent materials.

- Offering (Product or services)
- Value creation system (identifying customers and customer's requirements and expectations)
- Revenue (pricing structure, market, and network)
- The conceptual level of product structure (commercial and technical point of view)

It is essential to understand precisely what the customer is paying for. As a result, while the revenue reasoning may not appear significant, it is crucial to productize its business model. According to Tell (2020), when buying, consuming, or developing products, the

productization structure consists of three spaces that must all be considered. The *workspace (or problem space)* represents consumer aspects and includes work scenarios with associated needs and requirements. The producer side is represented by the *product space (or solution space)*, which contains products and features. The *change space* encompasses differences, compatibility, and changes between work conditions and effects, resulting in ties and relationships between work situations and outcomes. (Tell 2020)

The productization platform for water and wastewater treatment adsorbent materials is divided into two primary areas, as indicated in figure 6: clarifying offerings and building business strategy.

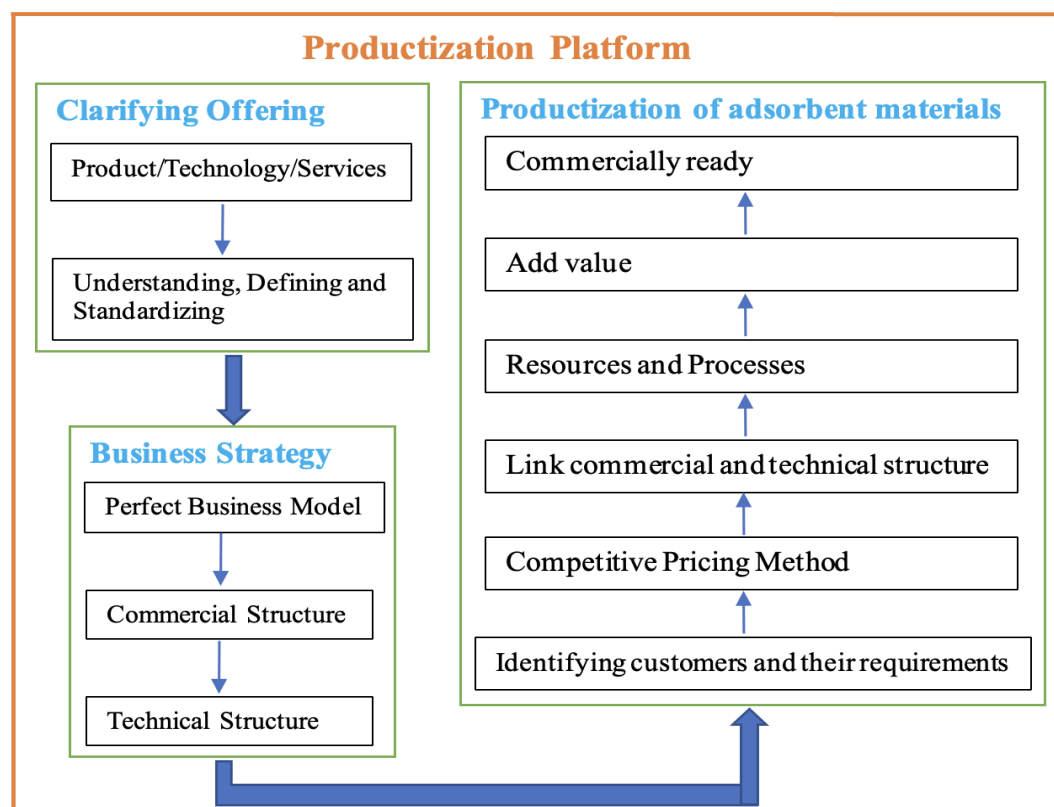


Figure 6. Productization platform of adsorbent materials for water and wastewater treatment [(Simula et al. 2008; Suominen et al. 2009; Harkonen et al. 2017; Elia et al. 2019)].

The first step is to determine the offering. The offering can be either technology or a product (adsorbent materials), or service—the identification assists in more precisely defining the offering and then standardizing the offering. Customers can be assured of the visibility and performance of novel offers if the organization has a complete and clear grasp of the offering.

The second step is to transfer the offering to the company's business strategy. Knowing the procedures and resources within the company allows for the creation of a great business model. A commercial and technical framework could be established by utilizing well-defined and specified resources and processes and establishing the connection between the structure is the productization of the offering. The offering's productization encompasses the identified customers, requirements, cost drivers, resources, and processes in the application. This integration adds value to the offering and prepares it for commercialization.

3 EMPIRICAL STUDY

3.1 Research Method and Process

This thesis uses a qualitative research approach to study the potential commercialization challenges of adsorbent materials for water and wastewater treatment, followed by adsorbent material productization. This chapter examines why qualitative research was chosen and provides a more extensive explanation of how descriptive research interviews were done in practice. In general, a researcher will be able to elaborate and improve existing thoughts and expand the thought process by using qualitative methods, assessing, and evaluating the concerns from a detailed viewpoint (Jamshed 2014). A case study is an empirical examination that explores a current phenomenon in its real-life scenario when the distinctions among occurrence and background are not apparent and numerous sources of evidence are utilized (Yin 2015). According to Zainal (2007), Case studies are being used to produce a complete picture and better understand the researched phenomenon, which entails studying and analyzing immense amounts of data within a particular circumstance. In a qualitative case study, interviews are a key source of data for data collection that aid or aims to acquire in-depth reflection on the issue (Jentoft and Olsen 2019).

For the present empirical study, several cases were selected to be investigated and analyzed individually. Since studying commercialization aspects of adsorbent materials is not new, empirical research will undoubtedly be required to draw on the expertise and knowledge of personnel from companies involved in the field. The subjective perspective of professionals is essential because it provides knowledge regarding drivers and barriers to product/service creation and improvement from a realistic and comprehensive standpoint. The primary goal is to examine the usage of the commercialization and productization concept and how enterprises have currently articulated and arranged their offerings. The empirical research process and case study analysis are discussed in Chapter 3 to get a practical understanding of adsorbent materials for water and wastewater treatment. The findings from both the theoretical and empirical studies are merged in Chapter 4 to provide a complete overview of the concepts and recommendations for practical deployment. Chapter 5 concludes the research's contribution and evaluation and makes recommendations for future research.

3.1.1 Research Design

Earlier literature from Google Scholar, Science Direct, and ResearchGate was reviewed to get practical knowledge regarding adsorbent materials. The empirical research used companies as the unit of analysis. Interviews with concerned technical experts at the case companies were the primary source of information for this thesis. Furthermore, before interviewing the respondents, the publicly available data, specifically the case companies' websites, were studied to gather as much information as possible on the company's commercial offerings and services. The pictorial representation of the research process is shown in figure 7.

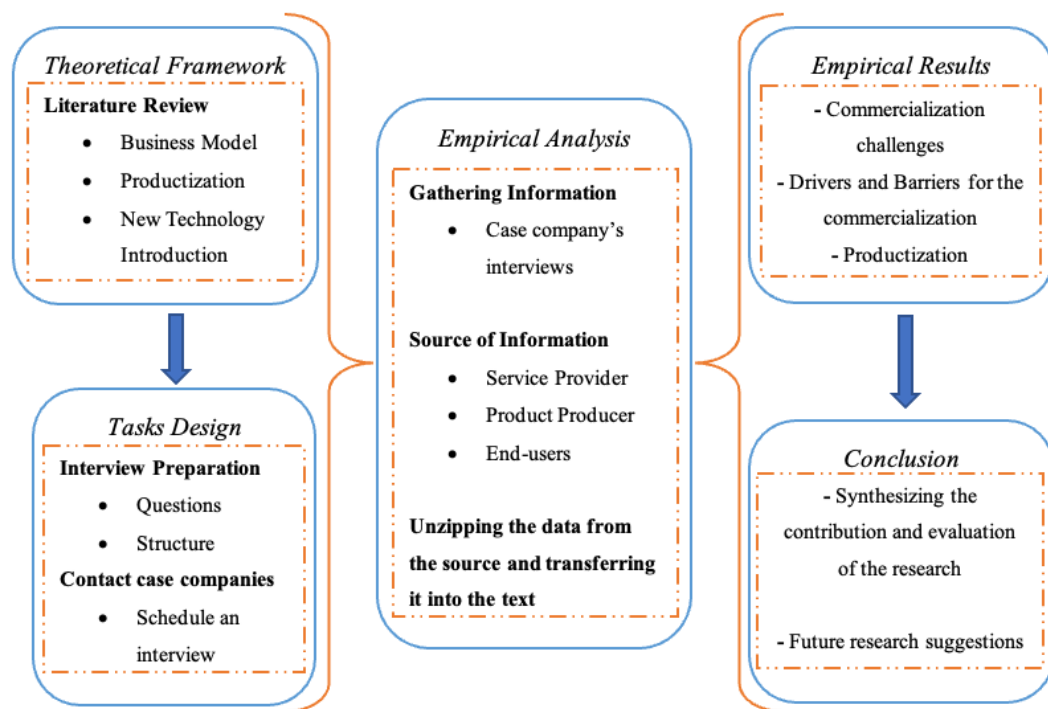


Figure 7. Research design and process.

The research focuses on the generic business model of adsorbent materials for water and wastewater treatment and its commercialization features and productization concerns. The multiple-case strategy can be used with actual events to illustrate many forms of knowledge through replication, improving, and confirming prior conclusions (Zainal 2007; Yin 2015). The first step in conducting empirical research was to create the questionnaire that would be used to lead the semi-structured interview (see Appendix 1). The preparation also included a thorough examination of the synthesis theoretical framework and past information and research about the topic. The layout of the interview

questionnaire, as shown in Table 4, had those themes since the literature review focused on the most recent and essential studies in business model, productization, and technology commercialization.

Table 4. Interview questionnaire structure.

	Current state – Future Potential - Challenges
Business Model	<ul style="list-style-type: none"> • Offering, value creation, and revenue model • Customer segmentation, customer role, and customer identity • Cost structure and pricing methods • Challenges in the business
New Technology Introduction	<ul style="list-style-type: none"> • Introduction of the product/services/technologies in the business • Source of new product/services/technology • Challenges in adopting new product/services/technology
Productization	<ul style="list-style-type: none"> • Product/Service identification • Commercial and technical product/service structure • Processes and resources clarification, identification, and understanding

The second step was to select and contact the companies that represent adsorbent materials producers and vendors, consultants providing design services for water treatment, and end-users of adsorbent products. The case companies were contacted and informed about the research topic and aims. Simultaneous website research was done to understand the firm, its product or service structures, processes, and descriptions. The interviewees were sent information regarding the research beforehand through email to acknowledge the study's objectives. Before the interview, the interviewees were given a structured questionnaire, which allowed them to prepare for the questions.

3.1.2 Data Sources

The sources used to answer the research questions are companies operating in the adsorbent materials industry, everyday clean water providers and consumers, and wastewater producers and managers. The companies working in the sectors of 1. water and wastewater treatment consultancy and process design, 2. companies producing or distributing adsorbent materials, and 3. companies with water and wastewater treatment

plants are the key source of data or information for this thesis. Companies in those three sectors were contacted through email to check about the possibility of conducting interviews at a suitable time. During an interview and data processing, GDPR (General Data Protection Regulation) guidelines were followed. The interviewees were informed beforehand about the research process and scope, asked for consent to record the interview, no confidential data were asked, and the information gathered was handled anonymously. As secondary data, various other data sources, such as publicly available research articles and reports, were explored. Even though twelve companies were contacted, only seven companies attended the interview. Three companies (A, B, and C) from the water and wastewater treatment consultancy and process design sector, two (D and E) from companies producing and distributing adsorbent materials sector, and two (F and G) companies from the water and wastewater treatment sector were interviewed. Although all case companies answered the same questionnaire, some of the questions may be irrelevant, particularly for the consultancy and water treatment process design company. The interviewed companies are all based in Finland, of various sizes, and offer expert services or products to both private and public customers. The critical tasks of the interviewed case companies are mining water treatment, industrial water treatment, and delivering clean drinking water to municipal residents. The summary of the interviewed case companies is shown in table 5.

Table 5. Overview of case companies.

Sector	Cases	Interviewee	Size
Water and wastewater treatment consultancy and process design	Company A	Process Engineer	Medium ¹
	Company B	Process Engineer	Large ²
	Company C	CEO	Small ³
Companies producing and distributing adsorbents	Company D	CEO	Small
	Company E	CEO	Medium
Companies with water and wastewater treatment plant	Company F	Development Manager	Medium
	Company G	Laboratory analyst	Small

¹ Company having employee more than 10 and supply water treatment infrastructure

² Company operating in Europe

³ Company having less than 10 employee

3.1.3 Data Collection and Analysis

The most prevalent data collection method in qualitative research is through interviews (structured, semi-structured, or in-depth) (Jamshed 2014; Yin 2015). However, the quality of the interviews can be ensured by collaboration between the researcher and the informant (Jentoft and Olsen 2019).

Data collection began once the semi-structured interview started. A virtual interview was conducted using the Teams meeting portal and lasted approximately one hour. The interview was open to impart understanding and opinions about the business model, resources, and application procedures of adsorbent materials more comprehensively and appropriately. The interview assisted in gaining an understanding about the company's offerings, services, and products; nevertheless, the significant accomplishment was learning how and when to use adsorbent materials in different water and wastewater treatment scenarios. In addition, it was an opportunity to learn more about the topic in detail and ask additional questions related and relevant to the topic. One of the data collection techniques for the research was secondary data (online available journal articles) related to the subject matter.

Following data collection, a qualitative method was utilized for the data analysis. First, the information from the interviews was unzipped and transferred into the text. Conceptualization to answer the research questions was then built, based on the theoretical background, research questions, and semi-structured interviews that demonstrated the in-depth findings and results of the issue. The findings and results were then analyzed and discussed to conclude the research.

3.2 Adsorbent Materials Overview

Before going on to the current state study of the case companies, it is essential first to describe adsorbent materials in general. This thesis section provides an overview of adsorbent materials, applications, and market size.

Adsorption is the process of a chemical species (such as an ion or molecule) adhering to a surface to recover or remove pollutants from a gas or liquid stream. Adsorption operations are widely used in chemical and biological processes, as well as in human life

activities. Adsorption is typically employed to remove natural organic matter or industrial pollutants with low concentrations from drinking water to improve drinking water's taste, color, or safety. Also, powerplants and many manufacturing industries use adsorption processes to produce process water. Adsorption activities are carried out with solid materials known as adsorbents (Sun et al. 2011; Gisi et al. 2016). Adsorbents are typically microporous or mesoporous materials with a high specific surface area (Sircar 2000) containing immobilized ligands or functional groups on the surface (Sun et al. 2011; Mahfoudhi and Boufi 2017). As potentially one of the easiest and cheapest ways to remove impurities and contaminants from water, the adsorption separation technique has gained popularity in various industries (Pourhakkak et al. 2021). Temperature, the type of adsorbate and adsorbent, the existence of other contaminants, and conditions in the process (pH, pollutant concentrations, contact time, particle size, etc.) all influence adsorption (Ali 2012).

In Figure 8, examples of materials used or studied as adsorbents are shown. The most commonly used materials are activated alumina, silica gel, activated carbon, molecular sieve zeolites, and synthetic polymer adsorbents (Knaebel 2011). When comparing adsorbent materials, the material cost is essential to consider. A low-cost adsorbent requires little processing, is available in nature, or is a by-product or waste content from the industry. Various natural materials that can remove pollutants from the environment at a low cost have been studied (Busetty 2019). Cost comparisons are challenging due to the limitation of reliable cost information. To further understand low-cost adsorption processes and show the technology, a lot of research and development is required (Bailey et al. 1999). In general, ideal materials for pollutant adsorption should meet the following criteria:

- Be inexpensive and can be regenerated using cost-effective methods.
- Have the excellent structural and mechanical integrity to withstand water flow for an extended period.
- Have high adsorption performance at high rates.

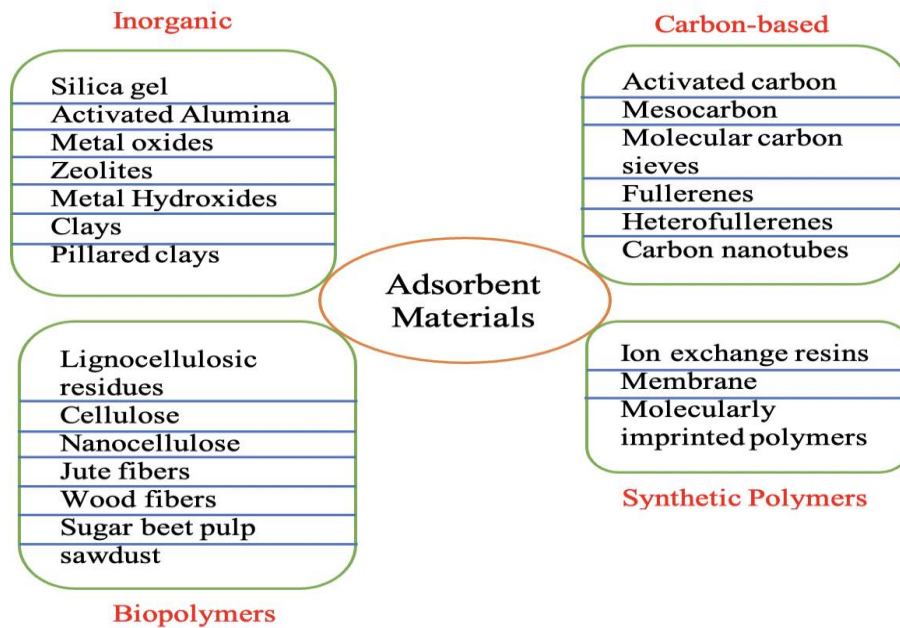


Figure 8. Available adsorbent materials in the market [modified from (Mahfoudhi and Boufi 2017)].

3.2.1 Applications and Market Size

Capability, specificity, renewability, dynamics, adaptability, and affordability are the most significant characteristics of an adsorbent for every application. The rapidly expanding environmental or quality standard adsorbent technology applications have made many previously difficult or impractical separations possible using traditional techniques like distillation, absorption, or even membrane-based systems (Knaebel 2011). Some adsorbents can purify fluids by eliminating impurities (gases or liquids). Other adsorbents can separate one kind of molecule from another in bulk. Each adsorbent's characteristics are tailored to the precise task at hand (Adeleke et al. 2019). So, it can be stated that water treatment, air conditioning systems, volatile organic compound elimination, air separation, natural gas, and petrochemicals are significant applications of adsorbent materials. Furthermore, frequently used adsorbents and their applications are shown in table 6.

Table 6. Examples of adsorbents and their applications.

Adsorbent	Examples of applications	References
Activated carbon	<ul style="list-style-type: none"> • Odour removal from gases • Purification of water • Vapor recovery from solvents • Helium Purification 	Knaebel 2011; Mahfoudhi and Boufi 2017; Adeleke et al. 2018; Busetty 2019
Activated alumina	<ul style="list-style-type: none"> • HCl removal from hydrogen • Adsorption of moisture 	Knaebel 2011; Mahfoudhi and Boufi 2017; Adeleke et al. 2018
Silica Gel	<ul style="list-style-type: none"> • Used as a desiccant • hydrocarbons separation • Natural gas dewpoint reduction 	Knaebel 2011
Synthetic polymers and resins	<ul style="list-style-type: none"> • Purification of water (decolorization) • Antibiotics and vitamins are recovered and purified. • Treatment of specific industrial wastes such as aqueous phenolics . 	Knaebel 2011
Zeolites	<ul style="list-style-type: none"> • the removal of a wide range of contaminants from both liquid effluents and gases 	Knaebel 2011; Mahfoudhi and Boufi 2017; Adeleke et al. 2018; Busetty 2019
Biomass	<ul style="list-style-type: none"> • Water purification • Removal of dyes from wastewater 	Bailey et al. 1999; Busetty 2019

The size and value of the adsorbent market are entirely dependent on the usage of the top consumers (both public and private). IMARC Services Private Limited (2021) states that the demand for adsorbents is segmented by product type, application, and geography. The adsorbent market is being driven by the increasing use of adsorbents in numerous applications, purity standards, and environmental concerns. According to Adsorbents Market (2021) report, the global adsorbents market is expected to reach USD 5.6 billion by 2026, growing at a CAGR of 5.9% between 2021 and 2026 from USD 4.1 billion in 2021 to USD 5.6 billion in 2026. Adsorbents are a diverse and competitive industry with many global participants and a small number of regional and local competitors. BASF SE (Germany), Arkema SA (France), Cabot Corporation (US), Axens (France), and Honeywell International Inc are some of the market's leading competitors, according to the Adsorbents Market (2021) report (US).

3.3 Current State Analysis of the Case Companies

The results of the empirical study are reported in this section of the thesis that is mainly concerned with assessing the business models, the introduction of new products/technologies, and the productization concept in the case companies. Considering companies in the areas of 1. water and wastewater treatment consultancy and process design, 2. companies producing or distributing adsorbent materials, and 3. companies with water and wastewater treatment plants as the primary sources of information, the empirical study's findings are discussed accordingly.

3.3.1 Water and Wastewater Treatment Consultancy and Process Design

As a result of global warming and industrialization, the issues of sustainable and environmentally responsible water governance have grown, so one of the community's most critical responsibilities is organizing water supply. Companies in this sector are primarily responsible for providing professional services such as designing water and wastewater treatment plants, planning and consulting tasks, materials research, and piloting and laboratory testing.

Company A is a Finnish water treatment and microbiological service company that works with customers to create novel measurement methods and water treatment equipment. Company A provides expert services or advice about designing, installation, maintenance help, water treatment equipment, and testing and piloting with their results/reports. The complete services provided by Company A assist people who wish to learn more about water conditions when there is degradation or damage, when technology is not functioning perfectly, or when strict environmental requirements are not being fulfilled. Industrial companies are the company's customers who approach them for services related to water treatment or quality issues.

Company B is a large company that serves as a European leader in engineering, process design, and consultancy services, with an international influence to help society transition to a more sustainable state. In the case of water, Company B in Finland provides municipal and industrial companies with design and consulting services that include a wide range of planning and advising activities in producing and distributing clean water,

wastewater treatment and management, and rainfall management. In addition to water treatment, company B offers infrastructure, process industry, and energy services.

Company C is a small Finnish company that researches waste and industrial by-products, their modification for reuse and safe disposal, conducts testing and piloting, and provides geotechnical design for quality control. In addition, the company produces adsorbent material to remove heavy metals, phosphorus, and arsenic. Company C specializes in water treatment, wastewater nitrogen recovery plants, and sludge drying solutions by utilizing municipal and industrial waste materials and side streams. Customers of Company C include companies in the wood processing, metallurgy and mining industries, wastewater treatment plants, municipalities, and contractors.

Business Model of the Case Companies

A business model is a strategy for a firm to produce revenue and profit from operations by addressing the following four key elements:

- Who are your clients?
- What is being offered for sale?
- How is it manufactured?
- How is revenue generated?

All the companies interviewed had a clearly defined business plan for their operations. All companies have demonstrated how they generate, deliver, and capture value.

Customers receive expert services such as process design, testing, piloting, and consultation services related to water and wastewater treatment from the companies interviewed in this sector. Company B has multiple areas (energy, process industry) to provide the relevant services, whereas Company C, in addition to the consultancy services, produces adsorbent materials. Since all three organizations offer expert services, their business models are similar, and they are all committed to providing excellent customer service. Customers of companies A and B include both industrial companies and municipalities. Company C, on the other hand, provides consulting and research services to industrial companies only.

Customers of the case companies contact the company for assistance. There is an unofficial and unstructured network where information about the companies involved in water and wastewater treatment can be obtained. The network means that customers have to know or can get information about the right service provider or manufacturer. Customers obtain information about the company through that network and contact the company for service. All the information available on the company's website acts as marketing. Other customers' feedback can sometimes be used as references for marketing purposes. Additionally, during a site visit, the visitor informs the client if the visitor notices anything that needs to be developed or improved. The rest of the treatment procedure or process design is carried out only if the customer requests it. As a result, there is no need for marketing in this industry. Because most projects are long-term, all companies have long-term relationships with their customers. It was also noted during the interviews that newcomers looking for good water and wastewater treatment services might not easily find a service provider unless they thoroughly understand the network. All three interviewees from the water and wastewater treatment consultancy and process design sector stated that necessary treatment services, process design, and many other services are only provided upon customer request. So as a result, delivering high-quality services, highly qualified information, the best solution, and inexpensive and straightforward services adds value to the organization.

Companies that produce adsorbent materials also aim to provide them as a service to their customers, so the revenue mechanism can be considered dependent on the services offered to the consumer. Company A has a predetermined price method for its services, but it is always dependent on the situations and services that clients select. It is sometimes based on the cost of doing business and sometimes on industry standards based on consumer value. Companies B and C compare the prices with other companies and set their prices. As consultancy services and process design require time to execute the tasks, the billing pricing is in euros/hour. They also state that the competitive pricing method is challenging for the business. Table 7 shows the business model overview of the case companies A, B, and C.

Table 7. Business Model overview of the case companies.

Offerings	Case Comp.	Customers	Value Creation System	Revenue Mechanism
- Testing and Piloting	A	Industry and Municipal	- Delivering high quality services and information	- Competitive pricing method
- Process Design	B	Mining Industry and Municipal	- Best solution	- Usually, its euros/hour
- Consultancy Services	C	Industry	- Inexpensive and straightforward services	

New Technology/Product Introduction in the Case Companies

Introducing new technology in case companies is critical since it is applied and focused on an organization's know-how. The scientific, technological, organizational, financial, and business activities that lead to a new (or improved) service for effective commercial exploitation are referred to as innovation in the studied companies. Companies must not only introduce or promote new technology to customers, but they must also evaluate and check the potential for new adsorbent materials. Introducing new technologies or products is difficult for both companies and customers.

Company A relies on manufacturers and peer-review publications about the new technology or product introduction. The company may recommend alternative or new adsorbent materials, technology, or services to analyze customer problems and results. Therefore, research activities and testing are the sources for the new technology or service introduction, depending on the case. The company needs to be knowledgeable about the manufacturers and the ongoing research activities regarding the customer's needs and recommend the best techno economically feasible solutions. In every circumstance, technology or product producers or suppliers should provide information on the technology or product's financial, technical, and efficiency elements.

Based on customer needs research, material development, and future outcomes, Company B prepares for the introduction of new technologies or services by planning ahead of time. New technology is introduced through technology providers, and information gathered from prior users acts as the source. Company B discovers that new products or technologies are rarely used in mining water treatment at an industrial scale. Pilot testing

is conceivable, and the customers want to ensure technical performance since water treatment costs are a significant consideration.

Company C, a producer of adsorbent materials, concentrates on adsorbent materials rather than new technology. Company C conducts lab testing and on-site piloting to introduce new products and services. By-products from the manufacturing process are used to create new adsorbent materials. The problems of new product introduction include material competition, identifying appropriate technical procedures, and finding the correct applications for the adsorbents. Table 8 shows the new technology/product introduction overview of the case companies.

Table 8. New Technology/Product Introduction overview of the case companies.

Case Comp.	New Technology Introduction	Source of new technology/product	Challenges
A	In-house R&D teams recommend new products/technologies based on customer problems.	Relies on manufacturers and peer-review publications about the new technology	Suppliers do not provide detailed information on the material's financial and technical (reliability, efficiency, etc.) aspects
B	In-house R&D teams plans and advice to use new product/technology	Technology providers and adsorbent manufacturers	New technologies are rarely used in mining industry
C	Lab testing and on-site piloting	By-products from industry	Material competitions, identifying appropriate technical procedures and applications

Productization Concept on the Case Companies

The productization concept is unfamiliar to the studied companies, and no ongoing development activities have been found. The companies' services are thoroughly detailed on their respective websites, which benefits users in understanding the services or products, but does not demonstrate a comprehensive understanding of the product or service commercial and technical structure concept. In general, offerings must be comprehended and maintained on both a commercial and technical level, including the understanding of sellable products or services and technical interrelationships.

Company A does not have a commercial and technical structure for the services. As they provide a service on customer request, they have developed a standard form: collect the

information, research, lab work/testing/piloting, and design a system. Customer's needs are always different from one another, so depending upon how much the clients want to pay and what they want to solve, the standard service structure of the company varies. The services provided are visible to the customer, and earlier references or feedback from those are acting as marketing. The water treatment-related problems and solutions of a customer cannot be freely disclosed to other customers: that is considered a trade secret. Therefore, the aims and outcomes of the services are only discussed or specified internally with the customers. The concept of co-creation is also highlighted in development, and thus new customers, must discuss their strategy, strategic goals, and how they can be aligned with company operations. Research is the process, whereas people are the resources needed to develop the services. Each process' parameter is defined and planned. Work hours are the primary cost structure, and there is a trend toward value-based pricing. Customers, the market, and competitors all determine value-based pricing. The selling price of a product, as we all know, defines the level of competition. According to one of the interviewees, the value-based pricing truth in the adsorbent industry is 1. the market impacts the price a customer is ready to pay for the product, and 2. competitors' prices can influence how valuable customers recognize a product. So, charging a higher price for the product may discourage potential clients from looking for a good deal.

Company B and C, on the other hand, lack the necessary commercial and technical frameworks to provide the services. Company B provides services based on customer segments, whereas company C delivers services based on the adsorbent materials' functionality or uses. Both companies do not advertise their services because they are based on customer requests. Developing the services in companies B and C involves preliminary lab testing, planning, and piloting. The most common price structure is euro/hour of working time, but competitive pricing is always used—the organization targets and plans value-based pricing to increase productivity and efficiency.

The studied companies had weaknesses regarding how their services could be marketed or productized. All companies follow a similar framework (issue analysis, research on issues to get the best solution, test/piloting, and designing/consulting). This shows that it was usually unclear which components of the services should be classified as commercial or technical. Close collaboration with the customer is generally required, especially during the preliminary stages of the project when establishing and developing project capabilities. On the other hand, the customers have no transparency of organizational

processes or involvement. However, the level of collaboration varies depending on the type of service, as certain services' primary objective is to represent and eliminate the customers' issues related to water quality and wastewater treatment processes. Table 9 is the summary of the productization concept in the case companies.

Table 9. Overview of productization concept.

Case Comp.	Commercial/Technical structure	Offering structured by	Process/Resources required
A	No (Only general structure that varies on customer needs)	Market Segments	Research is the process, whereas people are the resources
B	No	Customer segments	Preliminary test and plan/time and feedback
C	No	Functionality (applications)	Material research / industrial by-products

3.3.2 Companies Producing and Distributing Adsorbent Materials

Water is a valuable natural resource; it must be protected. Adsorption utilizing various materials is one promising technology since it is expected to be technically simple to implement, maintain, and cost-effective in cleaning water and wastewater. Two companies producing and distributing adsorbent materials were interviewed.

Company D is a small Finnish company that creates novel and unique water treatment products while also operating as a distributor for mining reagent manufacturers. The company has worked with customers to accomplish solutions for a wide range of environmental issues, including methods to concentrate of heavy metals for recovery. In collaboration, the company seeks customized, long-term water purification solutions. In addition to producing high-quality water treatment products, the company offers expertise and knowledge at customers' request, on-site analysis, testing, piloting, and economic global logistics and sales.

Company E is a new clean technology firm specializing in water technology and water treatment. The company's products are based on groundbreaking research and can remove soluble materials (metals) from wastewater. In addition to adsorbent products, the company offers adsorbent dosing equipment and fully customized treatment process equipment.

Business Model of the Case Companies

Both companies interviewed have a transparent business model that includes a detailed description of their targeted customers, a value creation system, and revenue mechanisms.

Company D manufactures a variety of chitosan-based solid and solution-form adsorbents primarily used for mining water treatment from mines. Mining industries are Company D's customers, and the company actively works with the customer to solve their problems related to water treatment. Solutions are provided at a reasonable cost upon customer request, including logistics activities from production to the final customer. The primary driver for adding value to the company and achieving the business model strategy is logistical work. According to an interviewee from company D, effective logistics at a reasonable cost for adsorbent materials manufacturing companies is challenging. In addition to logistics, REACH (Registration, Evaluation, Authorization, and Restriction of Chemicals) legislation, particularly in Europe, is a challenge. Each product must be registered, evaluated, and authorized according to REACH and the registration requirements can be prohibitively expensive for small companies. Pricing methods are offered in several ways to customers, depending on their preferences; some are provided in euros per mass of delivered adsorbent. On the other hand, some are required to pay euro per treated volume of water. Raw materials providers and technology companies in Finland are the partners of company D.

Company E manufactures inorganic adsorbents to remove arsenic and heavy metals from mining wastewater. The mining industries in Finland are contacted directly, or customers contact the company through a local agent. Company E, like other companies, serves customers based on customer demand. Prices for manufactured adsorbent materials are set in comparison to competitors' prices. Technology companies in Finland that supply the treatment process components are the partners of company E. Table 10 below summarizes the business model overview of the case companies D and E.

Table 10. Business Model overview of the case companies.

Case comp.	Offering	Customer	Value System	Creation	Revenue Mechanism
D	Chitosan-based solid and solution-form adsorbents.	Mining Industries	Effective logistics for their products		Competitive pricing methods (Invoicing per mass of delivered adsorbent or per treated volume of water)
E	Inorganic adsorbents		Simple and robust treatment process		

New Technology/Product Introduction in the Case Companies

Research on materials, customer issues, applications, and treatment processes is always the first step in starting any project. As a result, research is the only way to introduce new products/technologies into the adsorption industry. Both companies have their research and development teams, and collaboration with universities, technology partners, and the VTT research center is how new products/technologies are introduced. So, own research and collaboration teams are the sources of new product/technology development and introduction.

Company D, once it has an innovative idea for new adsorbents and has had a good discussion with R&D centers, could perform experiments with small-scale samples for customers. Then, the company discusses with end-users about their needs and the first impression the customer guides the process for further development of new adsorbent materials. Company D is more concerned with raw materials that could generate new adsorbent materials for water treatment, whereas company E is more concerned with adsorption technology applications. Piloting is done as a combined activity with the clients after a thorough discussion and definition of practical research efforts. In addition to environmental legislation, most customers choose products/technologies that have previously been adopted in the market or already been used by someone to prevent making mistakes is one of the complex challenges in introducing new products/technology. Table 11 summarizes the case companies D and E's new technology/product introductions.

Table 11. New Technology/Product Introduction Overview.

Company	New Technology/Product Introduction	Source	Challenges
D	Discussion with in-house R&D teams, small-scale testing, and discussions with end-user	Collaboration with universities, technology partners, and the VTT research center	- Environmental legislation - Customers prefer technologies already adopted in the market
E	combined activity with the clients after a good discussion and practical research efforts		

Productization Concept of the Case Companies

Both adsorbent manufacturing companies do not have the commercial and technical aspects well-modeled for their offerings. Product structure and productization are concepts that companies are utterly unfamiliar with. The interviewed companies manufacture adsorbent materials and provide high-tech products, services, and primary applications to various industries where customers' requirements can indeed be customized and implemented into the products. The concept of productization and product structure is a source of uniformity that would help to connect the commercial and technical structure of the product for better comprehension.

Company D does not use commercial and technical structure concepts. An interviewee mentioned that “both the structure depends upon the customer-oriented solution (application), commercial structure changes according to the customer’s demands whereas, the technical side is the modification which also depends upon customer needs.” Since the mining sector accounts for 95% of the company's revenue, the mining sector is the focus of the company, and mining is the market segment. The pricing process is quite open and transparent; products are often offered as priced per unit weight, with additional fees added based on the necessity for services. Developing products begins with the necessary research activities, testing, and work planning, as defined in the business model. People (employees), time, and raw materials are the three primary resources.

The basic concepts of the product structure (commercial and technical) are used in Company E, but the structures are not connected. The company controls marketing activities and has subsidiaries or agency contracts for sales in target markets. Apart from adsorbents, the company also creates and supplies process technology for water treatment

based on clients' needs; however, they are not adequately defined or represented in the commercial structure. In terms of technical structure, adsorbent production is carried out in-house, project process design is carried out in collaboration with external engineering firms, including the procurement of water analysis services, and process technology is sourced from partners. Customers can see the properties, test results, and advantages of the products because the application of the products determines the offering. The number of orders completed and the number of work hours per project are the company's cost-driving elements. The productization concept of the interviewed companies in this sector is summarized in Table 12.

Table 12. Overview of the Productization concept.

Case Comp.	Commercial/Technical Structure	Offering Structured By:	Process/Resources required
D	No (Structure depends on customers' requirements)	Market segments	- Necessary research activities, testing, and work planning is the process
E	Basic concept of the commercial and technical structure but are not connected	Customer segments	- People, time, and raw materials are the source

3.3.3 Companies with Water and Wastewater Treatment Plants

This sector's companies have their water and wastewater treatment plants under their operation. They provide clean water and manage wastewater for the public and industries. Companies in this sector use consulting services and adsorbent materials made by manufacturers. In other words, they are the clients of consulting firms and production firms. Two companies (F and G) were interviewed for this study to learn about their business models, new technology/product introductions, and productization concepts.

Company F provides drinking water to the public and takes care of wastewater. Besides that, the company works on planning, maintenance, and building of water distribution and sewer networks. In terms of water treatment and adsorbents, ion-exchange resins are the competence of **Company G**. However, electricity-generating is the company's core business. In addition to electricity generation, the company also provides district heating to the public and industrial buildings.

Business Model of the Case Companies

Activated carbon is used by Company F to provide drinking water. The company's customers include city inhabitants and industries who use water daily, and customers, like any other company, contact themselves if any services are required. The company's value is its drinking water quality and wastewater treatment performance, and they are consistently developing and delivering value at a reasonable cost. The pricing of given services is set based on the cost of production and profit evaluation. The price approach is euros/m³ of water delivered or received wastewater. The company's partners include activated carbon and technology vendors. One of the difficulties in using adsorbent materials is that providers do not provide clear information about the product's regeneration, disposal, logistics, and lifecycle.

As Company G generates heat, steam, and electricity, most of the company's customers are public and industrial buildings. The company's value is determined by the consistency with which water, steam, and electricity are delivered. Production of heat, steam, and electricity is continuous, and distribution is available 24 hours a day, seven days a week. The electricity pricing mechanism is based on the exchange electricity price, whereas the price for other services is determined by the services delivered. The company's partners are ion-exchange suppliers and consultancy companies. The challenges in this sector are long delivery periods and rising pricing for ion-exchange resins. Table 13 summarizes the business models of the case companies F and G.

Table 13. Business Model overview of the case companies.

Case comp.	Offerings	Customers	Value Creation System and Revenue Mechanism
F	Providing drinking water and wastewater treatment	The public and Industries	<ul style="list-style-type: none"> - Drinking water quality and wastewater treatment performance - Pricing euros/m³ of delivered drinking water or received wastewater
G	Generates heat, steam, and electricity	Public and industries buildings	<ul style="list-style-type: none"> - Continuous production and delivery reliability for water, steam, and electricity

New Product/Technology Introduction in the Case Companies

Company F is reluctant to adopt new products/technology since the delivered drinking water cannot be returned once supplied to customers. However, if necessary, the latest products/technology must be thoroughly tested in terms of chemical properties, material performance, and logistics activities. The product/technology must be acceptable socially, environmentally, and commercially. The product/technology should have been demonstrated to work in the water industry, and the most crucial point is that it should have been used elsewhere for the same reason. "Only papers and promises about the product cannot convince the buyers," a corporate interviewee said, "rather it should be displayed about the product and proven."

Company G, like other companies, is cautious about implementing new products or technologies because it cannot afford to risk affecting water quality, which would result in production disruption and high expenses. The procedure is slow and methodical, including extensive testing with an external consultant. To encourage the adoption of new products or technologies, the manufacturer should ensure that they work as intended, are less expensive than existing products and that the operation and maintenance of the novel unit processes are affordable and straightforward. The summary is shown in table 14.

Table 14. New Product/Technology Introduction overview in the case companies.

Case comp.	New Product/Technology Introduction	Source	Challenge
F	- Not ready to embrace new products/technology. If needed, products/technology must be thoroughly tested.	- Research and testing	- Risk of affecting water quality, production disruption
G	- The procedure is slow and methodical, including extensive testing	- Must be acceptable socially, commercially, and environmentally.	- Should have been used elsewhere for the same purpose

Productization Concept in the Case Companies

There is no need for marketing because the services provided by company F are a legalized monopoly and are legally controlled. Companies with water and wastewater treatment plants expect marketing from the producer since they use the product (adsorbent materials) generated by the producer. The organization has no commercial structure, but

in terms of technical structure design, they perform testing, piloting, and maintenance as issues in the treatment process; however, the methods and resources are not well defined. The cost-driving component is the raw materials required to produce drinking water and treat wastewater and the level of contamination in water.

Productization is a term that Company G is unfamiliar with, and there is no continuing development in this area. As a result, the interviewee did not respond to the question of productization. However, the company expects the service provider and producer to productize its products and services clearly and understandably and promote new and existing adsorbent materials. The productization concept summary of the companies interviewed in this sector is shown below in table 15.

Table 15. Productization concept overview.

Case comp.	Commercial/Technical Structure	Offering structured by	Process/Resources required
F	No commercial structure. Technical structure is not well defined	Market segment	Expect clear and understandable marketing of the new and existing adsorbent materials.
G	Not familiar with the productization concept	Customer segment	

3.4 Water and Wastewater Treatment Requirements

Several factors must be considered when producing adsorbent materials and service designs for water and wastewater treatment. Different sectors have different criteria or expectations, which must be recognized and utilized during the project development. The interviewees identified five essential requirements.

3.4.1 Material Requirements

The selection of adsorbent materials for the elimination of a specific adsorbate in adsorption-based water treatment procedures is determined by the relationship between the adsorbent's surface chemistry and the adsorbate composition and properties (Oladoja et al. 2017). The expectations and requirements of novel adsorbent materials include information on material efficiency, life span, regeneration, and availability. According to an interviewee from the water and wastewater treatment plant sector who is a customer

of the producer companies, the materials should be environmentally, socially, and economically acceptable that are tested and proven, not just the paperwork. All of the companies interviewed agreed that the regeneration of materials or disposal after using novel adsorbents should be clearly stated. For example, some components in water may be unsuitable for the activated carbon (could be for any novel adsorbent materials) and its capacity, so what is the solution? How about the life cycle of the materials? Activated carbon can be reused (regularly regenerated at a high temperature), but it is currently not cost-effective. For regeneration, they could be sent to Germany, but it is not cost-effective due to distances and service costs, so activated carbon is disposed of after the first use and is classified as hazardous waste. What is the waste disposal strategy?

3.4.2 Legislation and Standards Requirements

When producing adsorbent materials, various applicable laws and requirements should be reflected. Legal requirements are strict criteria that all businesses must meet. There is no choice but to adhere to the rules and standards. Legal requirements are among the most important for any enterprise since they cannot use their products unless they ensure compliance with applicable regulations. In many cases, the raw materials for adsorbents are by-products of the manufacturing process or waste. Waste, human health, the environment, and water and wastewater treatment control are all covered by European legislation and standards. Legislation and Standards requirements are rules and regulations that manufacturers, service providers, and users must adhere to. According to an interviewee from one of the manufacturer companies, environmental legislation is frequently burdensome when clients require a particular type of water treatment adsorbent to achieve better outcomes. As a result, different adsorbent materials or modifications are needed in this scenario, and each product must be registered, evaluated, and authorized according to REACH. This registration is expensive for the producers, and most customers are unwilling to pay these additional expenditures.

3.4.3 Cost Requirements

Cost is a factor that has always played a role in the corporate world. In the adsorbent business, too, the cost is a significant factor. A producer of adsorbent products should be able to assess the costs of raw materials, production, shipping, and handling, among other things. A service provider should be able to determine a reasonable fee for the service they deliver. Cost drivers in the adsorbent industry include research, testing, piloting, and

maintenance. As a result, these expenses should be set regardless of who pays for those cost-driving factors, the service/product provider or the customers.

3.4.4 Customer Requirements

All of the companies interviewed had customers who were industrial companies and municipal residents. Since products and services are only produced or delivered in response to consumer requests, those requirements must be met to receive positive feedback. The references themselves constitute marketing because the companies are not marketing their products or services. The company must ensure that they assist their customers in conducting excellent and flawless business, thereby offering value to its customers and building their connections. Customers value high-quality, highly skilled information and good services. Thus, products, services, and prices vary based on the customer. Customers may wish to participate in the process development efforts in specific situations.

3.4.5 Logistics Requirements

One of the essential requirements and expectations in the adsorbent materials industry is efficient logistics. Producers anticipate economical and straightforward transportation of raw materials and door-to-door delivery of finished goods. One of the production company's interviewees stated that they ship raw materials from China to Europe and finished products to the customer's place. He added, as a manufacturer, clients expect suitable logistic activities, but the cost should be agreed upon with the customers. Other interviewees in the water and wastewater treatment plant sectors, customers of producer companies stated that producers or suppliers should be responsible for delivering the product and removing the waste after use or for regeneration.

3.5 Customer's Expectations from Producers and Service Providers

Most customers are industrial companies (mining industries, paper industries, etc.) or municipalities (the public). Both customers carry out their responsibilities regarding waste management, human health, and environmental protection. Everyone in the adsorbent industry (producers and customers) should be concerned about human health and the environment. As a result, one of the critical customer expectations is that the product or service fulfill all of the essential requirements and be legally proven. Both

companies interviewed in the “companies with water and wastewater treatment plants” sector stated that the producers should be responsible for all relevant legislation and requirements.

Companies with water and wastewater treatment plants (producer's customers) should be cautious while distributing drinking water because it cannot be retracted if it is unfit for human consumption. The same is applicable for wastewater if it is released and is causing the thread to the environment. As a result, every customer expects adsorbent materials to have been thoroughly tested and validated, previously used for the same purpose, and cost-effective. This is also why adopting a new product or technology is challenging. Activated carbon is commonly used by companies that provide drinking water to city inhabitants. The maker of novel adsorbent materials should be responsible for regeneration; if the material is not reusable, the provider must provide disposal after use. This implies that the customer will require a product lifecycle plan in advance. The most crucial factor is logistics (bringing the product and taking it back after use). The novel material should be less expensive than existing materials, perform better than current materials, and provide clear and straightforward information on labor-related operations and maintenance. According to the customer's sector interviewee, new and existing adsorbent materials should be promoted more. "Recently, there was a modernization of the water plant, and it was quite difficult to find material sources for active carbon," he stated.

3.6 Producers and Service Provider's Expectations from Customers

“Customers should contact the producer or service provider if they require a product or service, and customers should be aware of the adsorbent materials network,” said the producer company's interviewee. One of the service providers stated that they could not advertise since a customer's water and wastewater problems cannot be published or shared with other customers for marketing. As a result, only customers' names are provided in the references for marketing. The producer and service provider believes that customers should come up with their problems (ask for solutions). Then the treatment plan (project) should start with sample testing, research, solution proposal, piloting, and plan implementation. Environmental legislation is sometimes challenging to implement. Many clients want a specific water treatment adsorbent to achieve better results. The additional costs of the legislation necessary for fairly standard technology with some adsorbents are

expected to be significant. On the other hand, customers are unfamiliar with adsorption and its benefits. Thus, adsorbent manufacture is done in small batches, which raises production costs.

3.7 Synthesis of the Empirical Findings

Most industrial companies and the public are customers in the adsorbent materials business for water and wastewater treatment. Municipalities in Finland serve city residents. Hence municipalities and other firms with water and wastewater treatment plans are direct customers of the adsorbent manufacturer. Essentially, adsorbent materials are necessary to treat wastewater generated by industries and household activities and supply city residents with safe drinking water. Manufacturers, service providers, and users work hard to keep the environment clean and offer safe drinking water. This activity necessitates more research, development, and testing to make it easily accessible and understandable to all direct and indirect users. Along with research and development, commercialization and productization of adsorbent materials should focus on practical elements:

- Adaptability to various pollutants (phosphorus, sulfate, arsenic, etc.)
- Adsorbent materials' technical reliability and efficiency
- The adsorbent materials' life cycle
- Workforce related to the operation and maintenance of the materials
- less expensive than the current one.
- Plan for regeneration and disposal
- Legislation and standards
- Advertising and promotion

An interviewee from the company stated that “only paperwork and promise on the product cannot convince the customers rather it should be demonstrated about the product and proven.” The statement implies that nobody wants to be the first user in the adsorbent industry. Everyone wants prior references and a track record for adsorbent materials makes commercialization difficult. Customers demand a great business model in the adsorbent material sector that gives information on material performance, functionality

and applicability, life cycle, and costs. Furthermore, new adsorbent materials manufacturers should answer the questions:

- How can customers easily buy?
- Who and how are logistics activities handled?
- How simple is it to manage the material (operation and maintenance)?
- What is the alternative strategy if the novel adsorbent materials do not work as expected?
- Who pays the costs of testing and piloting, and how much does it cost to accomplish the project?

Customers' needs differ depending on market segment, functionality and applications, and customer segment. After analyzing the three sectors of 1. consultancy and water treatment design, 2. companies producing or distributing adsorbent materials, and 3. companies with water and wastewater treatment plants - industrial companies (mining, paper, chemical industries) and municipalities were identified as customers who use adsorbent materials as a product or service (serving city residents). Table 16 summarizes and defines the offerings and identifies customers in each of the three categories. The 'consultancy and water treatment design' sectors, according to a study of the current status of the case companies, provide expert services and system design. They are not only looking for adsorbent materials to offer the best solution. Still, they might also employ various treatment options (such as ion exchange, membrane technology, and so on) to provide the treatment solution. Another sector, "companies with water and wastewater treatment plants," uses both adsorbent materials and expert services from manufacturers and consulting companies, respectively, and typically uses adsorbent materials for water treatment. On the other hand, manufacturers are the sole ones developing novel adsorbent materials and hoping to commercialize them. They are working along with researchers to develop and commercialize adsorbent materials.

Table 16. Offerings and customer identification of three sectors.

Sectors	Offerings	Customers
Water and wastewater treatment consultancy and process design	Piloting and testing, water treatment equipment, maintenance and training, and system design	Industrial companies and municipalities
Companies producing and distributing adsorbent materials	Manufacture and distribute adsorbent materials	Every company that uses adsorbent materials
Companies with water and wastewater treatment plant	Use products and services to produce clean drinking water and manage city wastewater	City residents and companies who uses drinking water

Municipalities and other companies having water and wastewater treatment plants responsible for supplying safe drinking water to city residents and controlling wastewater always prefer to utilize activated carbon. They are unwilling to use new products or technologies. On the other hand, industrial companies have a variety of metals as pollutants that must be eliminated from the factory's effluent before releasing to the environment. So, they're interested in novel adsorbents, but there are many factors to consider and follow. The main reason customers are uncertain about embracing novel adsorbent materials is that the producer or service provider should act by customer preferences. Customers contact the manufacturer or service provider to remedy their water concerns, to put it simply. Because most manufacturers and service providers have their own customers, they do not believe marketing and advertising are required. Customers have been utilizing services for a long time and have a long-term relationship with the supplier. As a result, buyers are unwilling to convert from one product to another until they have confirmation that the new product is superior to the previous one. Customers aren't interested in repeating testing and piloting. Table 17 compares the identified consumers of the adsorbent materials, as customer identification is one of the prerequisites for commercialization and productization. The comparison gives the manufacturer information on customers using adsorbent materials based on application, functionality, market segment, and customer segment.

Table 17. Comparisons between customers/users of the adsorbent materials.

Factors	Industrial Companies	Company serving public
Wastewater	Generates harmful waste	Household waste
Adsorbent materials	Suitable to remove pollutants from the wastewater	Mostly activated carbon to remove taste, color, or smell
New product/technologies	Looking for new adsorbent materials in less price	Not keen on using new product/technologies
Water matrix treatment costs	Comparatively high	Less than industrial companies
Product should be offered by	Functionality, application, and market segment	Customer segment
Contacts	The customer companies contact producer and service provider according to their needs	
Marketing and advertising	Customer companies are looking for marketing of the adsorbent materials and services by the manufacturer and service provider	

The purpose of the research is to advance the commercialization of adsorbent materials by productizing them. It has been observed that the producers and researchers of novel adsorbent materials are seeking commercialization. As a result, the focus of this study is on the productization of adsorbent materials (products). Customers and their requirements were identified, products were clarified, and business models were known based on the productization platforms of adsorbent materials and empirical research. This opens up plenty of possibilities for the commercialization of adsorbent materials. Despite the productization prospects, there are numerous challenges to overcome during the productization of adsorbent materials to advance commercialization. As a summary of the empirical research, the following opportunities and challenges have been identified and listed.

Opportunities:

- A clear productization idea provides the actual pricing structure and product-related aspects. A productized and uniform product description is essential for the product cost and performance projections.
- The product structure concept connects the product's commercial and technical structures for better understanding to deliver high-tech products, services, and

primary applications to various industries, where customers' needs can be adapted and applied to the products.

- The buyers can quickly get all of the necessary information (capabilities, reliabilities, lifecycle, test results, regulations and standards, regeneration or disposal, logistics, and costs) through a visual depiction of the commercial structure of the adsorbent materials. Newcomers to the adsorbent business, on the other hand, will benefit more.
- The technical structure of adsorbent materials demonstrates product development processes, cost drivers, time management, and resource use. Furthermore, the ability to track the project's development is a significant productization opportunity.
- The link between the commercial and technical structures gives a brief overview of sales and customer requirements and their connections to resources and manufacturing processes, which aids in large-scale production planning.
- Productization operations promote the introduction of products to the market by accomplishing tasks beyond product design and production that makes products comprehensible and adds value to customers.
- Productization establishes principles for standardizing operations, enhancing productivity, and increasing tangibility.
- Productization's describing, standardizing, organizing, and tangibilizing characteristics make products more competitive, efficient, and profitable to achieve consumer satisfaction.

Challenges:

- Users (especially clean water providers) are familiar with adsorbent materials like activated carbon because they have been using them for a long time. As a result, clients are often cautious about employing novel adsorbent materials without proof.
- Productization is a comparatively new term among interviewers, and companies feared that integrating productization would hamper manufacturing processes and entail more hard work.

- Every manufacturer and service provider has its own set of clients. Most of the time, products and services are made and delivered based on consumers' needs. As a result, the corporation does not promote its products or services.
- Customer requirements differ, which causes adsorbent materials' commercial and technical structure to vary. As a result, it becomes tough to recognize the specific elements of the particular design (structures).
- It is impossible to take any risks with the water quality since it would disrupt production and cause huge losses. Once water or wastewater is released to the customer or environment, it cannot be retracted.
- There are remedies for all types of water. However, costs vary greatly depending on the treatments. Water treatment costs rise as the procedure advances, but customers are rarely ready to pay more. Aside from this cost structure, the producer or service provider is worried about the cost of productization.
- Despite extensive adsorbent materials research for water and wastewater treatment, additional practical study on raw materials, regeneration, disposal, lifecycle, cost structure, and business strategies is still needed.

4 DISCUSSION AND RECOMMENDATIONS

Productization encompasses marketing and engineering, whereas commercialization is a more comprehensive and marketing-oriented approach. The goal of productization is to simplify and justify the firm's offers. On the other hand, commercialization is bringing innovation or products to market. As a result, productization refers to all completed operations before a product can be marketed and sold (Simula et al. 2008). Commercializing the products and services depends on effective business models and productization understanding. The recommendations for the adsorbent materials industry are linked to the theoretical understanding of business models and productization in this chapter and answer research question three.

4.1 Business Model Framework

According to the literature review, a constructive and descriptive business model framework is built around the business model elements (offering, value creation system, and revenue model) to gain insights into the functional requirements of the business, add value to the product, overcome technical difficulties and achieve the company's goal of generating revenue. The framework will assist the organization in describing its offering (composition, customer, and sales technique), value creation system (identify value-adding work, customer structure, and size), and revenue model (cost and pricing structure and market size). According to the empirical research, the central point from the interviews was that a business model's performance is inadequate, resulting in people's unwillingness to buy new products (adsorbent materials). In addition, despite detailed descriptions of their products and customers, none of the case companies have defined their business model. Therefore, based on the literature review, a business model framework is recommended with adsorbent business elements found during empirical research shown in table 18. The framework can be utilized to answer the following questions:

- How easy is it for customers to learn about and purchase the product?
- What are the typical customer requirements?
- How do you manage the product's sales channel, distribution, and billing?
- What kind of cost structure do you have in production and profit generation?

- What market is served, and how big is that market?

The answers to these questions help create scenarios for better business performance and monitor the business. In addition, the framework gives dimensions for evaluating business models. The evaluation parameters for the framework in the adsorbent materials business evaluate the business model elements that result in meeting water and wastewater treatment requirements and attaining customer (adsorbent materials end-users) expectations. The business model can serve as the foundation for product commercialization after all needs are met, customer expectations are acknowledged, and customers receive the necessary information regarding novel adsorbent materials.

Table 18. Elements for describing, building, and evaluating business models framework in adsorbent materials business.

Business Models Elements	Components	Description	Dimensions for framework evaluation
Offerings	Identification Product or service	What are the offerings?	Reliability and Capability Alternative Strategy
	Customer Identification	Who are the customers?	
	Distribution, sales, and Invoicing	How is the offering delivered? How do customers pay?	
Value Creation System	Identify value-adding work	What will the customer pay for?	Cost Structure (less expensive)
	Information about product for commercialization	What information are customers willing to know about the product?	Regeneration or disposal
	Customer structure (Size and Number)	How many customers?	Quality of the materials Research and Development
Revenue Model	Cost and Pricing Structure (Price based on value or cost)	What is the cost of production? What influences the cost of the product?	Suitability and Availability
	Offer structured by	Who is served?	Customer feedback
	Network Building	How extensive is the network?	

A reference business model of adsorbent materials for water and wastewater treatment is built using this proposed business model framework, as illustrated in table 19. The research and development activities on novel adsorbents are growing exponentially, and the adsorbent is anticipated to undergo fundamental changes and improvements. As a

result, the reference business model will serve as a business model canvas and a roadmap for implementing a business strategy in the adsorbent material market.

Table 19. Reference business model of adsorbent materials for water and wastewater treatment.

	Identification of the offer (product)	Customer Identification	Distribution, sales, and invoicing		Dimensions for offering evaluations
			Distribution and sales	Invoicing	
Offerings	Adsorbent materials as a product-oriented (Name of the product)	Industrial companies, municipalities	Cost-effective logistics, marketing, installation, and maintenance	Euro per mass of delivered adsorbent	Reliability and capability Regeneration or disposal
	Adsorbent materials as a result-oriented (Name of the product)			Euro per unit weight of the product used and/or Euro per volume of water delivered or disposed	Customer feedback Research and Development Suitability and availability
Value creation system	Identify value adding work	Information	Customer structure		Dimensions for value evaluation
	Clean & safe drinking water, pollutants removal, overall best solution	Legislation, test result/report, regeneration, disposal, costs, etc.	Number of customers, customers working sector		Alternative strategy Less expensive Quality of the materials
Revenue model	Cost and pricing structure	Offering structured by	Network building		Dimensions for revenue evaluation
	Cost based price, value-based price	Market segment, customer segment	Contacting customers, making an offer		Cost structure Network connection

4.2 Productization Framework

In general, offerings must be comprehended and maintained on both a commercial and technical level, including the understanding of sellable products and technical interrelationships. This could be accomplished by implementing a product structure that

considers commercial and technical aspects of the products or services due to the general product and service features. As a result, it is critical to assess the needs of actual and prospective clients, and this is accomplished through productization activities, which entails preparing a product for commercial use.

Commercial Structure

The commercial viewpoint is customer-oriented and provides information about products' sales and marketing, including contracts, offerings, shipments, and bills (costs). According to the current status of the case companies, adsorbent materials should focus more on customer requirements because most adsorbent materials are only offered in response to client requests. To make a product commercially available, a company must understand the elements visible to customers that aid in the commercialization of the product and the method to productize. The specific components for the commercial structure of the adsorbent materials are shown in figure 9.

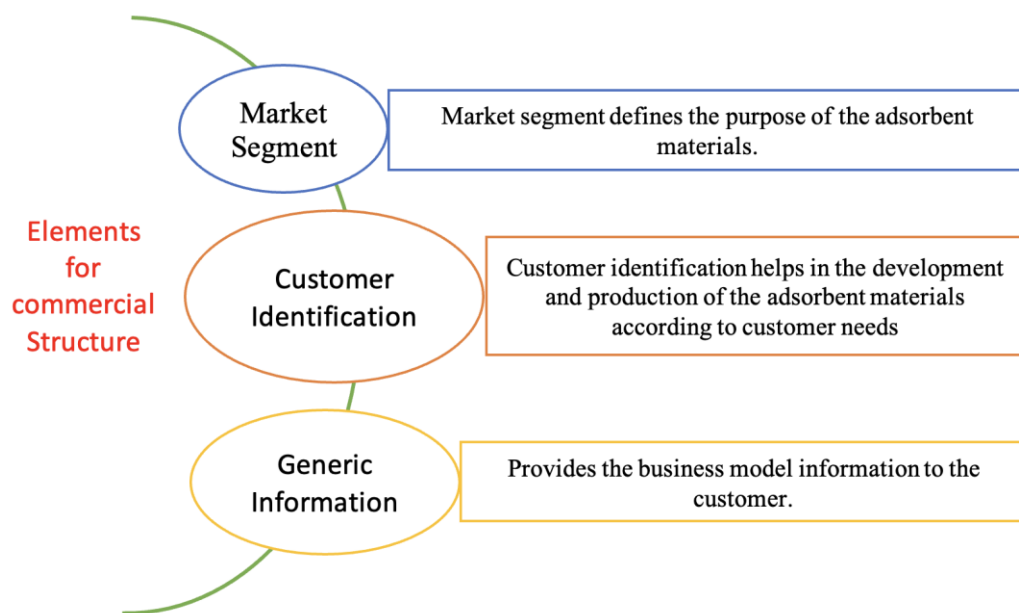


Figure 9. Commercial structure-specific elements.

Since water and wastewater treatment is a market segment, manufacturers and providers must first identify their target clients (industrial companies or municipalities). This means that a producer must know who the target clients are and the market segments in which the products are sold. Aside from that, the most crucial criteria for commercialization are general information about the developed adsorbent materials. According to an empirical

study, customers want to know about product capabilities, lifecycle, test results, legislation and standards, logistics activities, regeneration or disposal, and costs. Based on these commercial findings and literature analysis, a commercial structure for the productization of adsorbent materials is proposed in Figure 10.

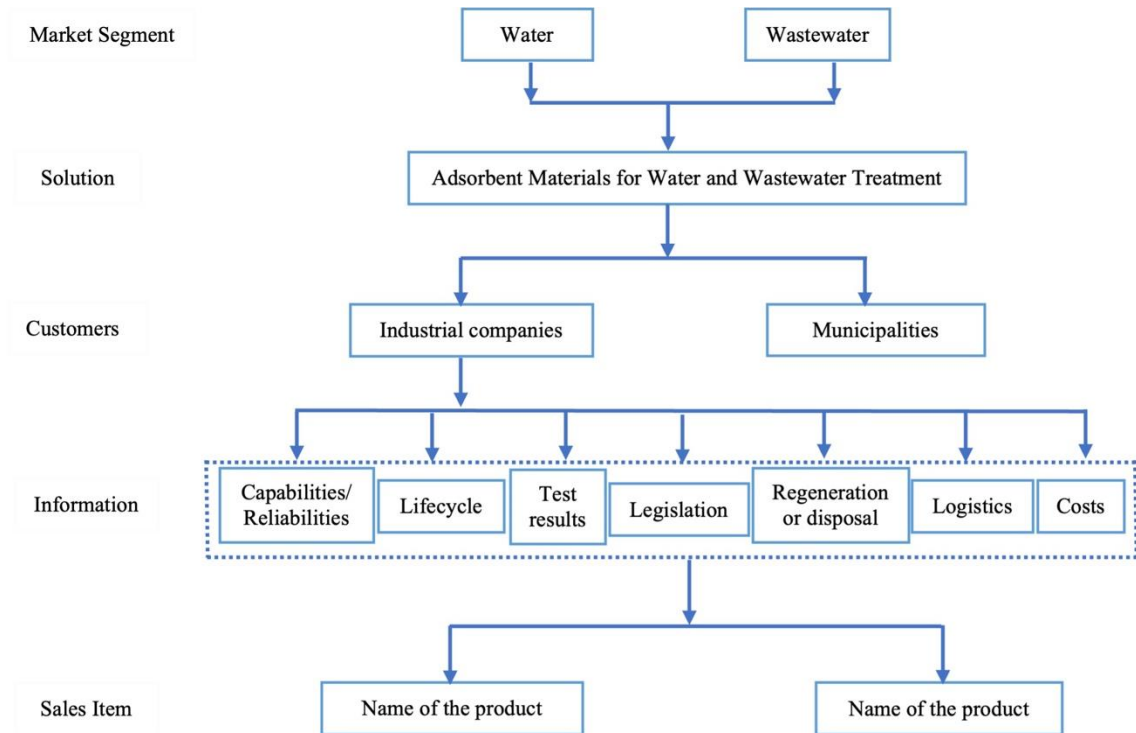


Figure 10. Commercial Structure of the adsorbent materials

Technical Structure

The technical viewpoint allows for a more in-depth understanding of research and development, planning, testing, and resource allocation. As a result, the technical aspects of the business include product development, manufacturing, service processes, and cost-driving elements. Though the company's technical methods vary depending on the expectations of its clients, a standard description procedure can be built to consider the necessary platforms. The platforms assist in determining the company's cost drivers and technological aspects. Those elements represent the company's techniques and procedures that are followed or carried out. The standard description approach is shown in figure 11.

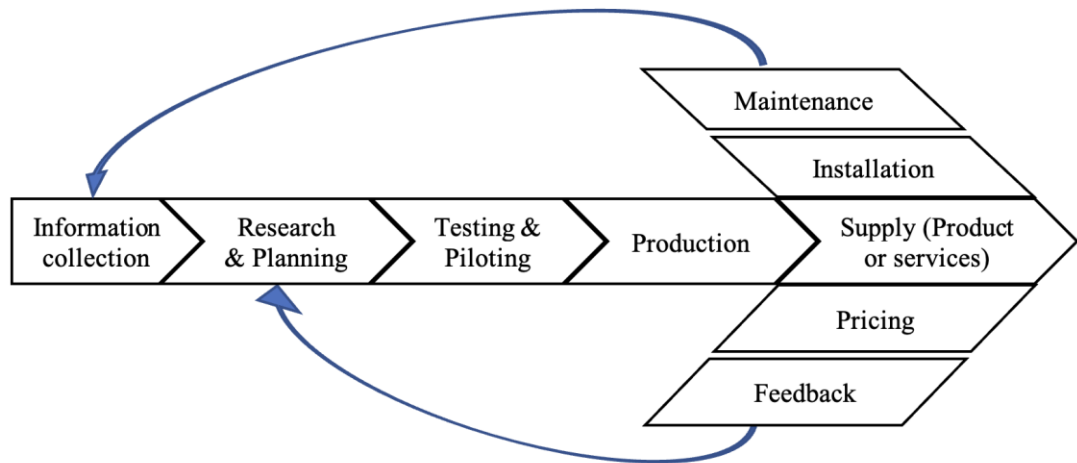


Figure 11. Standard value chain process in adsorbent business

Since there were no well-defined technical product structure elements, this standard framework can be used to identify the technical components and modules. This clear identification of technological factors fosters the development, production, and commercialization of novel adsorbents. Figure 12 depicts the technical structure of adsorbent materials based on these standard frameworks and technical element findings. *All of the interviewees stated that time is one of the most valuable resources. Still, there are no estimates or deadlines for each task or procedure, resulting in a lack of adsorbent materials.* The standard framework shows time calculations and allocations for each process and descriptions of each task at each stage of the technical process. Aside from research, the equipment used and customer feedback are also significant resources for adsorbent development.

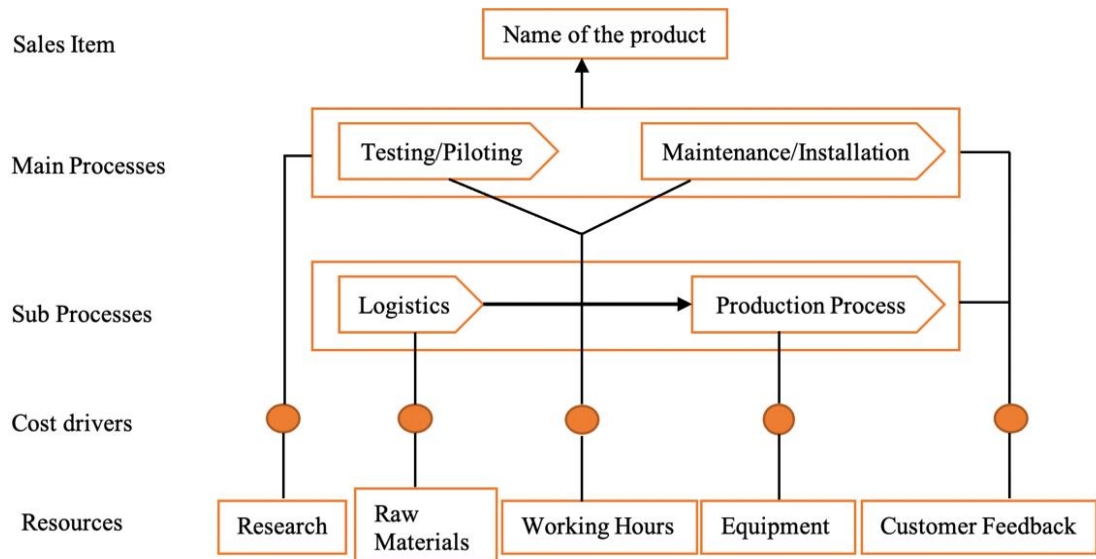


Figure 12. Technical structure of the adsorbent materials.

The commercial (visible to customers) and technical structure (visible within the organization) platforms should be linked to clarify offerings, assess internal and external (selling) costs and know standard processes and resources. This results in product structure logic that allows businesses to explain their offerings by specified processes and resources required to produce and assess their profitability.

Based on this research and findings, the key recommendations for the commercialization of novel adsorbent materials are that "the offerings can be offered as **adsorbent materials as a product-oriented** and **adsorbent materials as a result-oriented.**"

Figure 13 depicts the interlinked commercial and technical structure of adsorbent material production to advance commercialization, which is the proposed product structure of **adsorbent materials as a product-oriented** structure in this research. The customer selects the adsorbent materials based on the water and wastewater treatment requirements as a physical product. Other related complementary services (such as testing, logistics, and installation) can be provided. By analyzing cost-driving elements: a competitive pricing structure for the product can be established, production costs can be determined, the technical structure can be updated as needed, and processes and resources can be easily accessed. Furthermore, the novel adsorbent materials can be marketed and promoted.

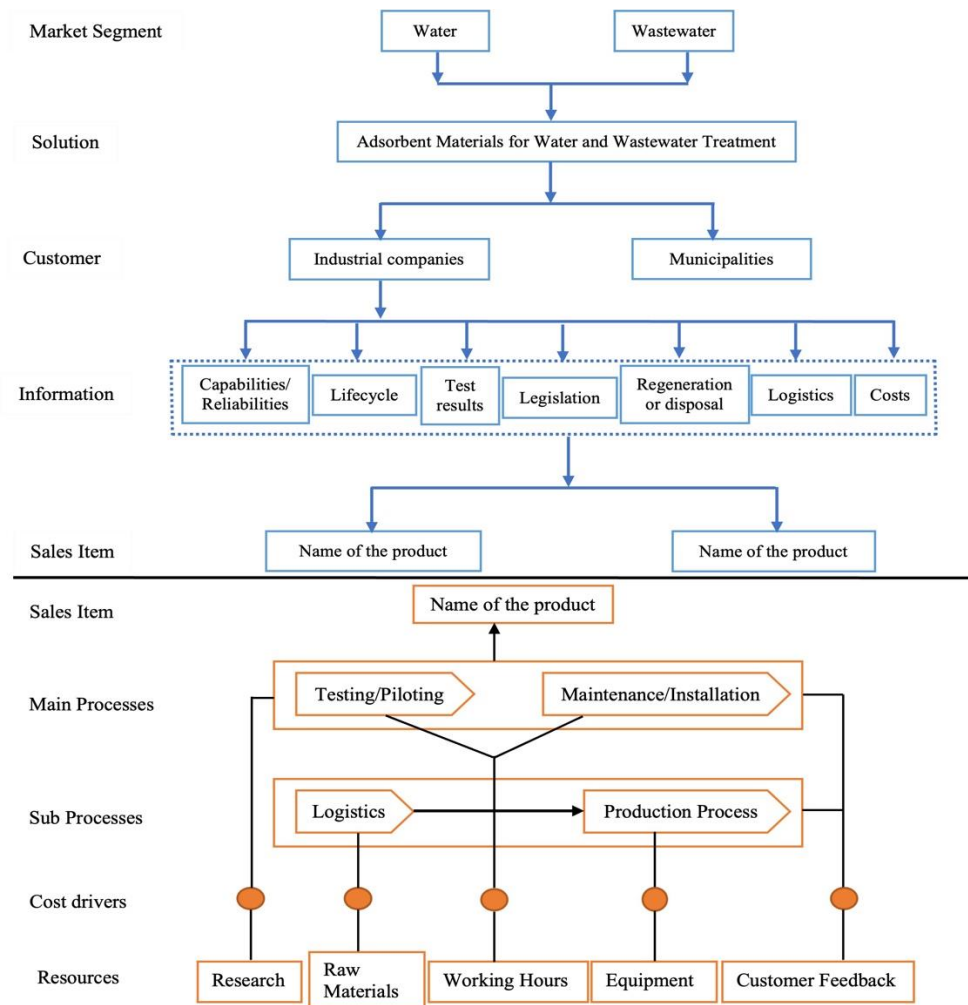


Figure 13. Adsorbent materials as a product-oriented.

Another recommendation made in this study to aid commercialization is to offer the **adsorbent materials as a result-oriented product**. The productization structure of adsorbent material as a result-oriented is shown in figure 14. The role of adsorbent materials, as we all know, is to treat water (to provide safe drinking water) and wastewater (removing the effluent). In this instance, the manufacturer can offer the adsorbent materials as a result-oriented service. This means that the customer only pays for the outcome. The volume of clean water, the amount of effluent to be removed, and the type of adsorbent materials used could all be the end outcome. The adsorbent materials can also be given on a contract basis to the customer. As customers pay for the results, the manufacturer is responsible for technical maintenance, product ownership, and other services (logistics, regeneration, disposal, etc.). The adsorbent materials provider holds most of the obligation to meet the customer's basic needs.

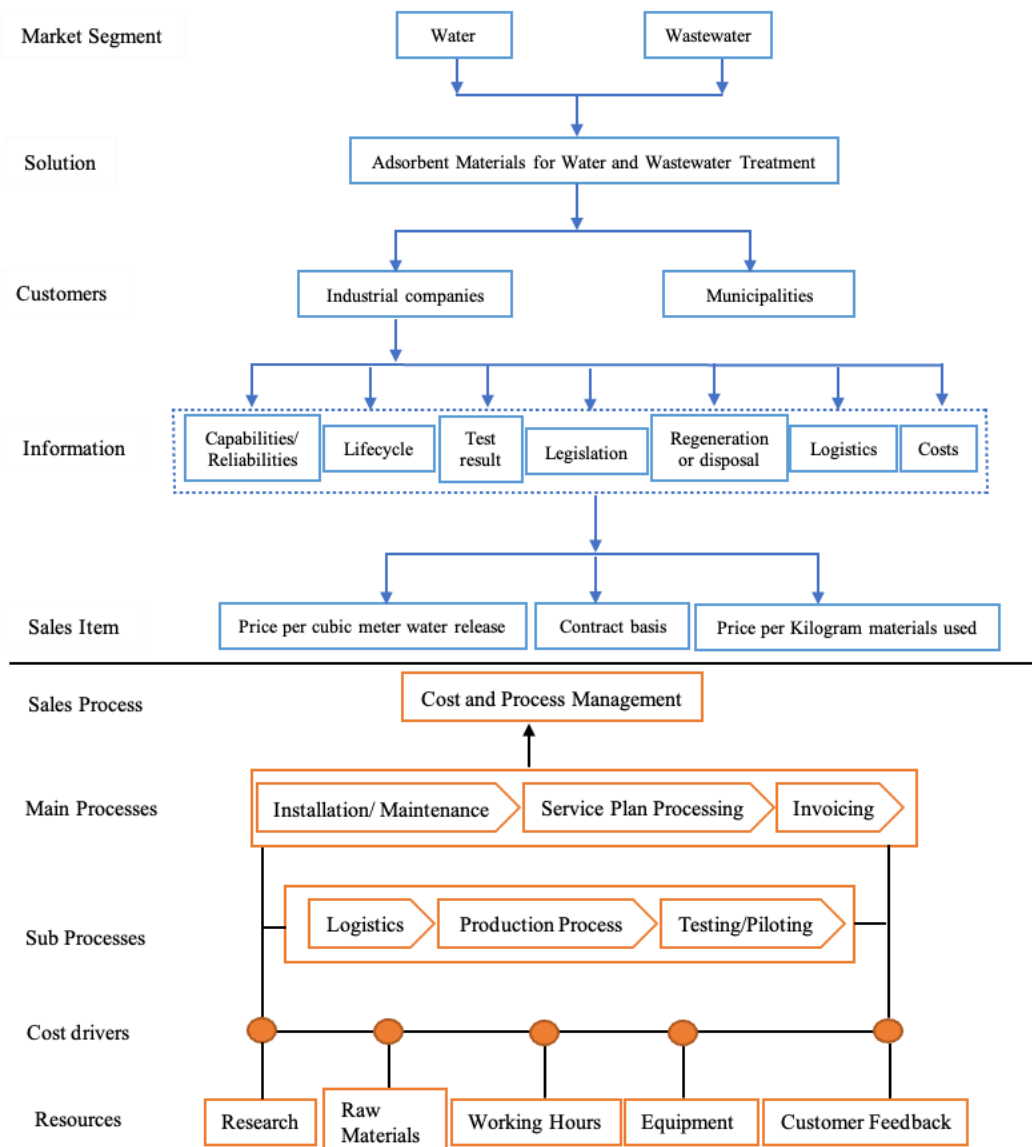


Figure 14. Adsorbent materials as a result-oriented.

The commercial structure is identical to adsorbent materials as a product-oriented structure; the only difference is the sales item. In adsorbent materials as a result-oriented scenario, the end result is the sales item. The technical structure's processes and resources are related to the commercial structure and can be adjusted depending on the sales item and customer needs. The production operations and billing rely entirely on the adsorbent materials' sales item. Implementing the cost and technical process is primarily driven by research and development activities and client feedback. Internal expenses can be computed depending on the tasks completed, which leads to a profitability calculation based on the outcomes.

5 CONCLUSION

The study focused on adsorbent materials for water and wastewater treatment business models, strategies, and techniques. The primary objectives of this study were to explore the concept of productization; analyze water and wastewater treatment requirements, producer requirements, and customer requirements; and develop business models and productization frameworks for the commercialization of novel adsorbent materials. The objectives of the research were accomplished by answering the three research questions. The theoretical basis of Business Models, Productization, and New Technology Introduction is covered in Chapter 2, answering the first research question. The research methodology, general information on the adsorbent materials, and the answers to the second research question were presented in Chapter 3. Finally, Chapter 4 discusses the recommendations, which addresses the third research question.

5.1 Main Contribution of the Research

RQ. 1. How can adsorbent materials for water and wastewater treatment be analyzed for productization?

The concept of productization refers to defining and merging customer needs into a product/technology/service. As a result, the productization platform (see figure 6) was built as a synthesis of the literature review to analyze water and wastewater treatment adsorbent materials productization. The productization platform is divided into two sections: clarifying offerings and developing a productization approach to support the commercialization of the offering.

RQ. 2. What are the opportunities and challenges in the adsorbent materials productization?

The case companies are from three sectors: 1. water and wastewater treatment consultancy and process design, 2. producing or distributing adsorbent materials, and 3. companies with water and wastewater treatment plants. Seven case companies are interviewed in all. The business models, new technology/product introduction, and productization concept of the case company were all analyzed (see table 7 - 15). The case

companies' business models are somewhat specified but not thoroughly documented. Companies are unwilling to adopt new technologies or products. The concept of productization is unfamiliar, and there are no continuous development efforts in the adsorbent materials industry. The results of the analyses lead to an assessment of the water and wastewater treatment requirements. Materials, legislation and standards, cost, customer, and logistics were identified as the five most essential requirements. Customers have an extensive list of expectations (reliable, tested and validated, cost-effective, logistics activities, and so on) from producers and service providers. According to producers and service providers, customers should contact manufacturers and service providers for solutions and be aware of the adsorbent materials network. These needs and expectations indicate that a manufacturer, distributor, and service provider of adsorbent materials should have perfect business models for product commercialization.

On the other hand, the productization of adsorbent materials assists in integrating these requirements and expectations into the product application by understanding and linking the commercial and technical structure of the product, resulting in a commercially successful product. As a result, it can be stated that the productization of adsorbent materials offers numerous opportunities. Despite the options, companies confront several challenges because the productization concept is new in the adsorbent materials business. The opportunities and challenges in the adsorbent materials productization were listed in the synthesis section (3.7) of Chapter 3.

RQ. 3. How should adsorbent materials for water and wastewater treatment be productized to advance commercialization?

A constructive and descriptive business model (see tables 18 and 19) and productization framework were recommended in response to the third research question. Based on this research and findings, the key recommendations for commercializing novel adsorbent materials were that "the offerings (adsorbent materials) can be offered as - adsorbent materials as a product-oriented (see figure 13) and adsorbent materials as a result-oriented (see figure 14)." Commercialization of novel adsorbent materials is aided by an effective business plan and perfect productization of the adsorbent materials. The business model identifies customers, defines customer requirements and expectations, measures market size, plans distribution and sales, and achieves profit generation, whereas productization combines these identifications and definitions into applications. The elements specific to

the commercial and technical structures were determined by examining the current state analysis and theoretical framework. Finally, to assist in the commercialization of the product, a commercial and technical design is connected and presented.

5.2 Evaluation of the Research

The positivist paradigm of case studies emphasizes reliability and validity as the two critical criteria for evaluating a research study (Rashid et al. 2019). Reliability is the level to which data gathering procedures or analysis techniques will give consistent results. If the research can be replicated in the future, the results are comparable, and the raw data is transparent, the study is considered reliable. Validity refers to whether the results are genuinely about what they seem to be. Construct validity, external validity, and internal validity are all types of validity (Saunders et al. 2009). To enhance the reliability and validity of this study, the following actions were used: defining the research process, using different sources of data, questionnaire designs and interviewing, and considering the thoughts of other experts.

The nature of this study is qualitative. The terms credibility, confirmability, consistency, and transferability are significant quality criteria in qualitative research (Golafshani 2003). Reliability is threatened by subject error, subject bias, observer error, and observer bias (Saunders et al. 2009). Research-related topics literature was reviewed from scientific publications and textbooks to develop the proper framework of the theory. The interview questions were carefully prepared based on the literature analysis and the research's goal. The interviewees were informed about the research themes and objectives to avoid subject bias. The interview took place at the time set by the interviewees. Based on a list of relevant subjects, semi-structured interviews were conducted. The interviews were recorded with permission and later transcribed to eliminate observer bias. For the truthfulness and reliability of the research, the interviewees were informed about maintaining confidentiality. During the interviews, no sensitive or comprehensive data about the business or its products/services were requested.

A case study approach was used in this research. A case study is viewed as a follow-up method in qualitative research. Robson and McCartan (2016) defined as a case study is a research technique that entails doing an empirical analysis of a current event in its real-world environment using numerous sources of information. The case companies were

chosen from the sectors that produce, distribute, and provide services of adsorbent materials to meet the research goals. The companies in the case study are based in Finland and have been in the adsorbent business for years. Since the study used a literature review and empirical results, the study's findings can be characterized as a generalized analysis. This research's recommended approach and results can be implemented in other novel adsorbent materials business models and commercialization procedures. This increases the research's credibility and transferability. Because of the nature of the study and the ongoing changes in companies and their business, the researcher is unlikely to come up with the same research conclusions. The acquired information and findings, on the other hand, are readily available for further research that can yield the same results and conclusions.

5.3 Future Research

Several issues that require more research were discovered during the research process. Adsorbent materials have usually been seen as manufactured products resulting from manufacturing. However, they are also offered as services. One of the most interesting and beneficial topics in the future could be researched on adsorbent materials as a service (productization of services).

According to the findings, most researchers are focused on developing novel adsorbent materials, with relatively little research focused on the large-scale production of the best-developed novel adsorbent materials. As a result, future research could concentrate on the large-scale manufacture of commercially viable adsorbent materials.

During the research, it was observed that logistics operations are challenging and impact the commercialization of adsorbent materials. As a result, additional studies in logistics management for cost-effective logistics might be conducted. Logistics encompasses the supply of raw materials to the manufacturing industry, the delivery of manufactured adsorbent materials to the end-user, and the transportation of used materials (which could be hazardous) from the end-user to regeneration or disposal.

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APPENDIX

Appendix 1. Interview questionnaire

Background questions:

1. Name
2. Background, current position

Business Model:

1. What adsorbent materials do you currently develop, use, produce, or sell?
(Product or services)
2. Who are your customers? (Both indirect and direct customers)
3. How do you interact with the customers?
4. What do the customers value, and how do you deliver value at a reasonable cost?
5. When and how do you produce the products? (On customer request or any other)
6. What type of pricing methods is used for the products/services?
7. Who are your key partners?
8. What type of challenges exist related to adsorption-based products in your business?

New product development / Technology Commercialization:

1. How do you introduce/adopt new adsorption-based products /technologies in your business?
2. Who/what are the sources of new products, services, or technologies?
3. What challenges exist in new product/technology introduction/adaption related to adsorption-based products and processes?
4. How could these challenges be overcome?

Productization:

1. Do you have a commercial and technical product/service structure for the offering (For adsorption-based products or services)?
2. Are the current products/services offering structured by: market segments, customer segments, product families, resources, applications, or something else?
3. What is visible to the customer on a sale of products/services?
4. Do you have a commercial product structure that helps, especially marketing and sales activities, to show customers what they can buy?
5. Do you have a technical product structure that helps define the needed processes and resources?
6. What are the processes and resources needed or required to produce or develop your product/services?
7. What are the cost-driving factors?
8. Is there cannibalization in the adsorbent materials business in water and wastewater treatment? If yes, do you consider cannibalization a problem?
9. Is there anything else you would like to add to adsorption-based products and processes?