Tampere University

Mio Silvennoinen

CUSTOMER VALUE IN COMMERCIALIZATION OF SUSTAINABLE INNOVATIONS

Cellulose-based 3D printing material and technology

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ABSTRACT

Mio Silvennoinen: Customer value in commercialization of innovation – Cellulose-based 3D printing material and technology
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Examiners: Professor Leena Aarikka-Stenroos and Doctoral researcher Sami Rustholkarhu
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To create value for economic growth, new technologies need to be transferred into products that can generate sales. Many fully commercialized technologies fail because unsuitable commercialization strategies. Due to the need for renewable and recyclable materials and sustainable production methods, innovations are emerging. Therefore, new tools to evaluate potential of sustainable innovations are needed. Realizing customer value early in commercialization process is categorized to be one of the success factors in technology commercialization. However, this factor is stated to be under-researched. This study tries to investigate how early identification and understanding of customer value can support and facilitate the commercialization process. Additionally, environmental values are included in the evaluation.

To meet the research objective, a literature review and qualitative case study was conducted. The case selected is a publicly funded multi-national research and development project with aim of creating a novel cellulose-based 3D printing material and technology. The case project is called NOVUM. The literature review will focus on the known benefits of the technologies, customer value, commercialization process of technologies, challenges in commercializing technologies, and utilizing business models in commercializing process. The data was collected through six semi-structured interviews. The uniqueness of this case was the opportunity to study customer value of potential end users in an early phase of the commercialization process. Also, much of secondary data from the case project was utilized. A thematic analysis of the data was conducted for obtaining the goals. A theoretical framework for commercializing technology was created and experimented in this study.

This study shows that early participation of end users and understanding the real potential customer value can help companies to evaluate different commercialization strategies and recognize the key resources and processes required for creating and delivering the desired customer value. Realizing what truly delivers value to the customer can facilitate the commercialization and adoption of innovations.

Keywords: customer value, commercialization, R&D exploitation, open innovation, sustainable manufacturing

TIIVISTELMÄ

Mio Silvennoinen: Asiakasarvo innovaation kaupallistamisessa – Selluloosapohjainen 3D tulostusmateriaali ja -teknologia
Diplomityö
Tampereen yliopisto
Konetekniikan diplomi-insinöörin tutkinto-ohjelma
Tarkastajat: professori Leena Aarikka-Stenroos ja väitöskirjatutkija Sami Rusthollkarhu
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Uusia teknologioita tulee viedä uusiksi myyviksi tuotteiksi talouskasvun mahdollistamiseksi. Monet markkinoille viedyt tuotteet epäonnistuvat sopimattoman kaupallistamisstrategian takia. Suuri kysyntä uusiutuvista ja kierrätettävistä materiaaleista sekä kestävistä tuotantotavoista synnyttää uusia innovaatioita. Tämän vuoksi on kysyntää uusille työkaluille, jotka arvioivat kestävien innovaatioiden potentiaalia. Asiakasarvon ymmärtäminen aikaisessa vaiheessa kaupallistamisprosessia sanotaan olevan yksi menestyksen avaimista teknologian markkinoille viemisessä. Tätä on kuitenkin tutkittu niukasti. Tämä tutkimus pyrkii selvittämään, kuinka aikaisessa vaiheessa tunnistettu ja ymmärretty asiakasarvo pystyy tukemaan teknologian kaupallistamista. Tämän lisäksi ympäristöarvot otetaan mukaan analyysiin.

Tutkimustavoitteen saavuttamiseksi suoritettiin kirjallisuuskatsaus ja kvalitatiivinen tapaustutkimus. Valittu tapaus on julkisrahoitteinen kansainvälinen tutkimusprojekti, jonka tavoitteena on kehittää uusi selluloosapohjainen 3D tulostusmateriaali sekä 3D tulostusteknologia. Projektin nimi on NOVUM. Kirjallisuuskatsaus keskittyy teknologioiden tunnettuihin hyötyihin, asiakasarvoon, teknologian kaupallistamisprosessiin, teknologian kaupallistamisen haasteisiin sekä liiketoimintamallin hyödyntämiseen teknologian kaupallistamisprosessissa. Tutkimusdata kerättiin kuudella puolistrukturoidulla haastattelulla. Tutkimuksen ainutlaatuisuus piilee siinä, että potentiaalisten loppukäyttäjien asiakasarvoa päästiin tutkimaan aikaisessa vaiheessa kaupallistamisprosessia. Tämän lisäksi analyysissä käytettiin paljon projektin sekundaaridataa. Tutkimusdataa hyödyntäen suoritettiin temaattinen analyysi tavoitteiden saavuttamiseksi. Teoreettinen viitekehys teknologian kaupallistamiseksi luotiin ja sitä käytettiin tässä tutkimuksessa.

Tämä tutkimus osoittaa, että loppukäyttäjien osallistuminen kaupallistamisprosessiin ja todellisen asiakasarvon ymmärtäminen voi auttaa yrityksiä vertailemaan eri kaupallistamisstrategioita sekä tunnistamaan pääresurssit ja -prosessit, joita tarvitaan halutun asiakasarvon luomiseen ja toimittamiseen. Innovaatioiden kaupallistaminen ja käyttöönotto helpottuu, kun ymmärretään mikä oikeasti luo arvoa asiakkaalle.

Avainsanat: asiakasarvo, kaupallistaminen, tutkimuksen hyödyntäminen, avoin innovaatio, kestävä tuotanto

Tämän julkaisun alkuperäisyys on tarkastettu Turnitin OriginalityCheck –ohjelmalla.

PREFACE

Six years ago, the biggest dream of life so far came true when I was accepted to study at the Tampere University of Technology. At that time, this thesis seemed as a distant subject. I started out as a Mechanical Engineering student but over time Industrial Engineering and Management started to interest me more and more. And now we are here. I got this incredible opportunity to write my thesis in an inspiring environment about a fascinating topic where I really could apply in practice everything I have learned through these years. For that I want to thank VTT's organization and specially my supervisors M.Sc. Alina Ruonala-Lindgren and D.Sc. Heli Kangas.

Thank you to my University and my examiners Professor Leena Aarikka-Stenroos and Doctoral researcher Sami Rusthollkarhu for your encouragement and advice. While studying in Tampere, I have enjoyed a great teaching and lived the best years of my life so far. Therefore, I want to thank my best mates there Ilmari Pohjavirta, Johannes Salo, Jyri Raninen, Mikko Rajamäki, Mikko Siren, and Mikko Suonpää. Not forgetting my tutors. We had a blast! Luckily nowadays we all have a camera with us all the time so we can live those moments over and over again. Next, I would like to thank my friends I met during my exchange studies in Groningen. I will never forget the warmth and spirit I experienced with you.

Finally, I would like to thank my family in my native language. Tack mamma. Kiitos isä ja sisarukseni Nino, Nana ja Otto. Kiitos suunnannäytöstä sekä kaikesta tuestanne ja rakkaudestanne, jota olen kokenut elämäni aikana. Tässähän alkaa olemaan jo aikamoinen teekkarisuku kasassa! Lopuksi kiitos elämäni rakkaudelle Essille ihan vain siitä, että olet olemassa.

Helsinki, 8 September 2021

Mio Silvennoinen

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LIST OF ABBREVIATIONS

ABS	acrylonitrile butadiene styrene
AM	additive manufacturing
CAD	computer aided design
CER	commercially exploitable result
CRF	Centro Ricerche Fiat
CVP	customer value proposition
ELV	end-of-life vehicles
EPS	expanded polystyrene
EU	European Union
FCA	Fiat Chrysler Automobiles
FDM	fused deposition modelling
FFF	fused filament fabrication
FGF	fused granular fabrication
Hitachi ABB PG	Hitachi ABB Power Grids
MT	Meyer Turku
OEM	original equipment manufacturer
PLA	polylactic acid
PP	polypropylene
R&D	research and development
SME	small and medium-sized firm
TRL	technology readiness level
3D	three-dimensional

1. INTRODUCTION

In this chapter, this study is introduced to the reader. First, the background of the study is presented. The motives, importance, and need of this study are described. Second, the research objective and scope are presented. In this section, information about the goals and research questions are introduced. Third, the structure of this paper is presented and discussed briefly. Last, the case of this study is introduced. The case project and its partner organizations are presented in this chapter.

1.1 Background of the study

Commercialization is said to be the most crucial phase of the technological innovation process (Chiesa & Frattini, 2011). Still, around 40 percent of commercialized new products fail (Castellion & Markham, 2013). Although the new products are functionally and technically superior to the competitors' offering, they can fail because of an insufficient launch strategy. This has even greater emphasis in high-technology markets, which have a fast-moving, volatile, and uncertain nature. Commercialization measures in high-technology markets have a stronger impact on the performance of the launch than in traditional markets. (Chiesa & Frattini, 2011) Market conditions have changed after economic reforms. Organizations are under constant pressure to perform well, deliver quality, and conducting this while keeping the operational costs as low as possible. It is important for organizations to differentiate themselves by capabilities and competencies to sustain in today's market and meet customers' need. (Gupta et al., 2013) Adopting novel manufacturing technologies and materials is a way to answer this demand.

The positive impact of research and development (R&D) activities on the growth and productivity of companies, industries and countries have been demonstrated by multiple studies over many decades (Becker, 2015). It is argued that the annual return of investment is around 20 percent in publicly funded projects (Hines, 2017). However, there is a much greater risk in R&D projects than in other types of investment because of the novelty of the new product or process (Guzzini & Iacobucci, 2017). European Union's (EU) continent-wide R&D programs will gather all the talent and money together to generate complex R&D projects and supply chains that would not otherwise occur. The largest EU's R&D program Horizon 2020 is spending 77 billion Euros from 2013 to 2020. Publicly funded R&D also corrects market failures such as the need of translating knowledge towards tackling societal challenges and uncertainty over profitability of basic research. The direct benefits of R&D are employees hired to conduct the R&D activities, services, licensing revenues, spinouts, and sales and tax revenue from new products and services. Indirect benefits of R&D are increased number of useful instruments, knowledge, and methods, more skilled workforce, and increased productivity of the firm adopting the new technology. (Hines, 2017) However, many researches have stated that the technology transfer and commercialization is the most important and direct outcome of public R&D projects (Jung et al., 2015). To create value for economic growth, new technologies need to be transferred into products that can generate sales (Kirchberger & Pohl, 2016).

World's population is skyrocketing, every day by 227 400 people. The capacity of earth is on the limit. Furthermore, unsustainable production with non-renewable materials increases global pollution and accelerates climate change. Only 10 percent of plastics are recycled, 60 percent end up to landfills, and the rest are unaccounted. If the current trend remains the same, in 2050 plastic industry needs 20 percent more supply of crude oil. (Bandyopadhyay & Heer, 2018) The changing legislation is demanding for more sustainable and material efficient manufacturing methods and using of more sustainable and recyclable materials (Immonen et al., 2021). 3D printing and biomaterials such as cellulose are considered to be a solution to this global problem (Bandyopadhyay & Heer, 2018; Immonen et al., 2021).

In this study, the commercialization potential of a publicly funded multinational R&D project's results is studied. The objective is to find ways how to maximize the success rate of the commercialization and to ensure an effective exploitation of the R&D results. This objective is tried to achieve by analyzing customer value of innovation. How realizing customer value can help managers to commercialize innovations? The R&D project is studying cellulose-based materials in 3D printing process for industrial scale applications. The goal is to design a new sustainable, energy and material efficient manufacturing concept and to develop a bio-based material to be used as raw material in this process. In this study, the commercialization refers to the launch of new product to the target market. The case project NOVUM and its consortium is presented later. The consortium consists of various stakeholders in the value chain such as raw material supplier, research institutions, technology providers and end users. The study tries to find out what are the benefits that each partner is potentially obtaining from the project and if the R&D results are adopted into their value chains. The sought benefits are the key input in analyzing and defining the customer value. Customer value will create the framework how innovations should be commercialized so the launch would be as successful as possible. The reasons why each partner is participating in the project and how the results are planned to be exploited vary significantly between project partners. Therefore, also the sought benefits and customer value are substantially different. The commercialization tasks and strategies are conducted with help of information collected from the project partners and how they are planning to exploit the technology.

NOVUM project is funded by Horizon 2020 program. In Horizon 2020, project participants must conduct an exploitation plan. This will be conducted in parallel with this study. Exploitation plan will describe how partners are exploiting the results of the R&D project. Exploitation of results refers to the actual utilization of the project's results after funding for the project ends. There are different types of exploitable results that can be scientific, societal, political, economic, commercial or for improving public knowledge. The exploitable results must be recognized, and their stakeholders or beneficiaries must be identified in the exploitation plan. The direct or indirect value that the exploitable results will deliver and their impact to each stakeholder must be concretized. (Ala-Mutka, 2021)

The exploitation plan should also recognize the risks and barriers of exploitation and then propose countermeasures to mitigate or eliminate these challenges. Also, the concrete measures that will ensure the exploitation should be described. The measures should be engaged already during the project. The roles and responsibilities of different partners in the exploitation and the supporting roles should be clear. (Ala-Mutka, 2021)

1.2 Research objective and scope

A comprehensive literature review about success factors in technology commercialization have been made by Kirchberger and Pohl (2016). Realizing customer value of the new technology was categorized to be one of the success factors. However, they further state that this factor seems **under-researched** and it should get more attention in university context. This shows a clear research gap in the previous research. "An early understanding of what truly delivers value, could be a powerful argument in commercializing the technology." (Kirchberger & Pohl, 2016) This study tries to bridge that gap by analyzing customer value in the case project.

The purpose of this paper is to study how analyzing customer value of potential end users can facilitate the commercialization of technological innovations. Especially, new emerging sustainability-focused innovations like 3D printing and cellulose-based products are in the scope. Analyzing customer value of these kind of innovations could have various of benefits because of the disruptive and uncertain nature. The innovations can have a great impact on the industry and there are applications that are still unexplored. Also, the sustainability aspect of innovations and its environmental value to end users need to be evaluated. The case project is a publicly funded multi-national R&D project. The results of the project and how they will be exploited are still unknown. Therefore, the R&D results and their boundaries need to be first defined closely, and then, the benefits of each result for individual partner need to be studied. These customer perceived benefits are studied for understanding the **customer perceived value**. One major question is what are the factors that affect the commercialization of innovations and what are the drivers. In this study, these targets are tried to achieve by analyzing customer value and benefits. The perceived benefits are the starting point that will guide the commercialization process of the innovation (see figure 1). The next step is to find out what are the measures to be conducted for ensuring an effective exploitation and a successful launch of innovation. For maximizing the success rate of commercialization, measures to overcome the challenges need to be identified and planned before the launch. Therefore, general as well as case specific factors that create challenges and barriers in commercialization process are studied. Innovations are important for the growth and competitive advantage of companies and therefore a successful launch is a critical stage of the process. To reach these objectives, a theoretical framework will be created. The framework is a general tool that can be utilized in future R&D commercialization projects.

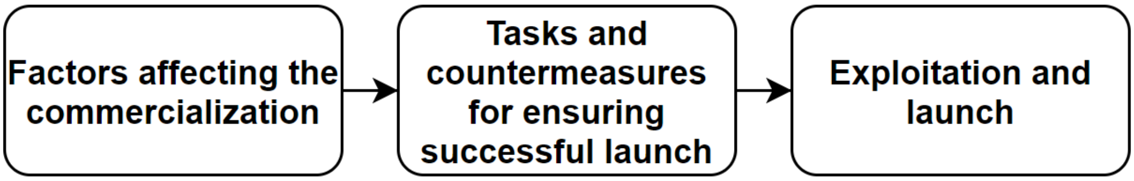

Figure 1. *The process of the study.*

The research questions are studied through case study. The uniqueness of this study is the end user involvement and the possibility to study customer perceived value before the initial launch of the innovation. The study is also interesting because of the uncertainty regarding innovations and the number of players that will exploit the R&D results. In the scope of this study is five partners of the case R&D project. In this study, the commercialization is studied from the viewpoint of developers and end users. All the partners represent different industries. Their offering, material requirements, demand, and markets are completely different which complicate the exploitation of the results. Therefore, a solution that would satisfy all the partners is needed.

The execution of this study consists of two phases. In the first phase, literature review, earlier studies and theoretical background of the technologies and technology commercialization is analyzed. Technologies regarding NOVUM project; 3D printing, fused granular fabrication and cellulose-based material and their contribution towards sustainable manufacturing is discussed. Technology commercialization part discusses about the process, elements, and challenges. Information was collected from several scientific articles, literature, and websites.

The second phase consists of the empirical part of the study. In this phase, the empirical data collected in interviews are analyzed and discussed to reach the objectives of this study. The study uses qualitative semi-structured expert interviews as the primary research data collecting method. The interviewees are representing the partner organizations in the scope of this study. Therefore, the answers they offered suit best for their organization and their targets, and thus cannot be generalized for the entire field of industry. Although generalized conclusions can be drawn.

1.3 Structure of the report

This report consists of five main chapters. Chapter 1 is the introduction of this report. It will discuss the background and objectives of this study. Chapter 2 consists of literature review and theoretical background of the study. In this chapter the existing literature is reviewed to give understanding of the existing knowledge about the topic. It will first discuss about the known benefits of the technologies and materials. Then customer value proposition is discussed and how it is interconnected with the benefits. The customer value proposition will guide the commercialization process which is discussed last. The commercialization part will focus on the process, challenges, and structure. Chapter 3 consists of the methodology of the study and how the study is conducted. In this chapter the process of this study is discussed. Research methods, data collection and analysis are presented. Also, the research is evaluated. Chapter 4 consists of the results of this study that were collected with the primary data collection method, interviews. The chapter will present how each partner sees the situation. Chapter 5 consists of analyzed and discussed findings of this study. It will also have the greatest emphasis in this report, because the chapter answers to the research questions and presents proposals for commercialization approaches. Different modes are compared and discussed. The chapters 2, 4, and 5 will all fairly close follow the process of benefits -> customer value -> commercialization.

1.4 Case description

In this chapter, the case of this study is introduced. The research objectives are tried to achieve through a case study where the case organizations are interviewed. The case consists of NOVUM project and its group of members called consortium. The consortium consists of 9 partners from 5 European countries. The partners represent several steps along the value chain. (NOVUM, 2020) However, in the scope of this study is only two R&D partners and three end users. The end user involvement in this study is a unique opportunity to obtain knowledge of customer value that will guide the commercialization process. The partners are representing three different industries, a research institute, and a technology provider. The end users representing different industries are all large multinational companies. The selected partners are the main beneficiaries of this project and the project's results can have a significant impact in their performance. From now on, the end users are referred as the original equipment manufacturers (OEM). The structure of this chapter is as follows. First, the NOVUM project is generally introduced. Second, the project partners that are in the scope of this study is introduced in alphabetical order. Last, other members of the consortium are briefly introduced.

NOVUM project

NOVUM is Horizon 2020 funded R&D project with aim to develop and demonstrate a cellulose-based 3D printing material, technology, and manufacturing concept. The project started in 2017 and will end in 2022. The Cellulose has been used in 3D printing earlier but as a filler in other plastics such as PLA. In this way of using cellulose, the cellulose content cannot be higher than 30 percent in the material. (Wang et al., 2018) The developed cellulose-based 3D printing material is called NOVUM material. In NOVUM material cellulose will be the dominant raw material. The technology development will focus on the industrial scale 3D printer capable of using NOVUM material. The designing of manufacturing concept will merge the novel material and technology and create a fully automated production line where post-processing is integrated.

Another technology that is studied in NOVUM project is fibrous foam printing. Fibrous foam is porous and lightweight material which can be used for replacing foam plastics. As in NOVUM material the main raw material of fibrous foam is cellulose but in much higher content because fibrous foam does not need to be thermoplastic and therefore additives are not needed. The development of fibrous foam printing technology started during the NOVUM projects when a need for this type of material was identified. Therefore, the development is lacking behind the other innovations created in NOVUM project. The applications studied in the project are electrical insulation components and parts for automotive and shipbuilding industry. In figure 2 applications are introduced. From left, the first picture illustrates electrical insulation components used in electric power transformers. The second application is replacing plastic parts in vehicles. The third application is fabricating decorative elements such as bar in the picture for shipbuilding industry.

Figure 2. *Application areas of NOVUM project; electrical insulation components and parts for vehicles and cruise ships.*

In the final stage of NOVUM project, a pilot line will be constructed where the technologies and the manufacturing concept are validated. (NOVUM, 2020) The pilot line will be a fully automated production line consisting of 3D printer and post-processing line. The 3D printer will conduct the fabrication where the post-processing line will have tasks related to finishing the surface and quality control. The technology readiness level (TRL) of the manufacturing concept in end of the project will be 6, which means that the technology is demonstrated in a relevant environment. TRL is used in Horizon 2020 for evaluating the maturity of the innovation. (European Commission, 2014) In the beginning of the project only one OEM partner was in the consortium and three different fabrication technologies where studied for different types of products. However, the constitution of the consortium has changed over the years and in the final stage of the project two more OEM partners have joined the project and only one fabrication technology is chosen to be part of the manufacturing concept. The value chain of the scope of this study is introduced in figure 3. For more detailed and broader value chain see Appendix A. The OEM partners are representing different field of industries: electric power transformers, shipbuilding, and automotive. The R&D partners have their own expertise and responsibilities in the development.

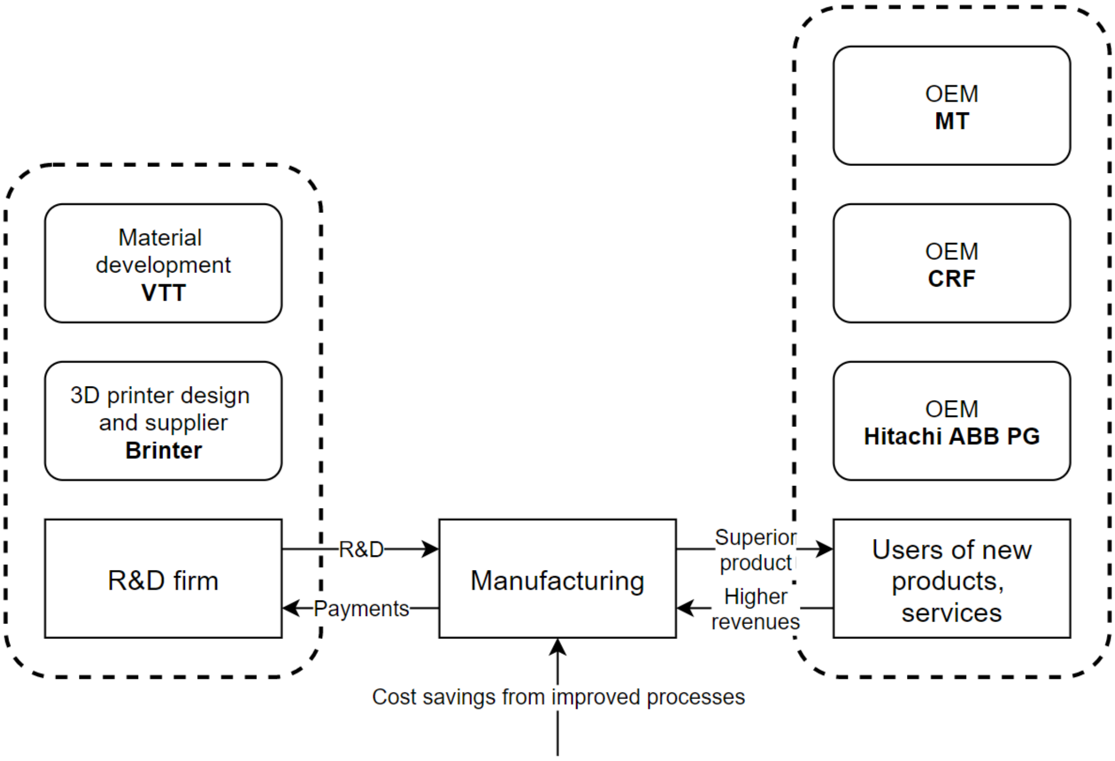

Figure 3. *Simplified value chain of NOVUM project.*

Brinter

Brinter is a Finnish bioprinting company. They provide 3D printing solution and services for pharmaceutical, biotechnological, and cosmetic industries, universities, and research facilities. All their products are custom built. (Brinter, 2018) Bioprinting is utilized in tissue engineering and regenerative medicine. The operating principle is same than in ordinary 3D printing, but the feedstock is combination of biomaterials and living cells called bioink. The end products are engineered tissues and organs. (Ozbolat, 2017)

Brinter is one of the R&D partners in NOVUM project. As the technology provider in the project, their main responsibility is to design and build a large industrial scale 3D printer that can be feed with cellulose-based material. The built 3D printer will be implemented in the pilot line. The printer will utilize multi-material 3D printing and fused granular printing technologies which are discussed more in the chapter 2.1 3D printing and sustainable manufacturing.

Centro Ricerche Fiat

Centro Ricerche Fiat (CRF) is the research and innovation division of Fiat Chrysler Automobiles (FCA) (after the merge with Groupe PSA the name changed to Stellantis). CRF develops and transfers innovation to FCA’s products, vehicles. CRF’s portfolio includes powertrains, vehicles systems and features, materials, processes, and methodologies. Three principal axes of sustainability guide their operations: environmental, social, and economical. They conduct much of collaboration at national and international levels with the aim of industrial exploitation of research. (NOVUM, 2020)

Although CRF is a research and innovation division they are referred as one of the end users in NOVUM project (OEM partner). Their objective is to replace fossil-based plastics with biomaterials in parts of FCA's vehicles. They entered NOVUM project in a later phase.

Hitachi ABB Power Grids

Hitachi ABB Power Grids (Hitachi ABB PG) manufactures, designs, supplies, and maintains transformers, reactors, transmission and distribution network solutions, power grid management guidance, automation, and control systems. They are operating in a field of energy and electricity companies, industry, transport, and infrastructure. Hitachi ABB PG's target is built a stronger, smarter, and more environmentally friendly energy system. They are a multinational company with locations in 90 countries and 36 000 employees. (NOVUM, 2020)

They are one of the original OEM partners in NOVUM project. Their objective is to exploit NOVUM technology in fabrication of electrical insulation components, which are used in electric power transformers. The current insulation components are made of cellulose, but the manufacturing process is time and energy consuming and labor-intensive. The process consists of multiple stages. The insulation components are handcrafted by using molds, generating a significant amount of waste and need for organizing and storing thousands of molds. After molding, insulation components are dried which is a highly energy consuming process.

Meyer Turku Oy

Meyer Turku Oy (MT) is one of the leading European shipbuilding companies. MT and its predecessors have had shipbuilding operation at Turku Shipyard since 1737. During the time, shipyard has built over 1 300 ships for customers around the world. They are designing and building innovative, tailor-made cruise vessels and ferries. MT invests in environmentally friendly, energy efficient, and safe production. They provide state-of-the-art technology solutions, advanced construction processes and cutting-edge innovations for cruise operators. MT is a family-owned company with operations in Turku, Finland and over 2 000 employees. However, because of the broad subcontractor network of MT, the maritime cluster employs over 30 000 people in Finland. (NOVUM, 2020)

MT is one of the OEM partners that entered NOVUM project in a later phase. The scope of the products in this project are decorative elements in the passenger deck; facades, pillars, and bars to name a few. These elements are also called outfitting because they are installed in the outfitting phase of the vessel. The demand of these parts is uneven because the parts are only needed in one phase of the vessel's construction process.

VTT Technical Research Centre of Finland Ltd

VTT Technical Research Centre of Finland Ltd (VTT) is the leading research and technology company in the Nordic countries. They provide research and innovation services for private and public partners. VTT helps customers to create new products, production processes, methods, and services. They mission is to promote sustainable development, employment, and well-being. VTT offers also top of line research facilities and a broad range of intellectual property right and licensing services. (NOVUM, 2020)

As a research institute VTT is the second R&D partner in the scope of this study. Their main responsibility is the development of cellulose-based 3D printing material, NOVUM material. Furthermore, the development of fibrous foam printing technology is in the responsibility of VTT. VTT is also the official project coordinator and therefore this paper was commissioned by VTT.

Other partners

There are also many partners in NOVUM project that are not in the scope of this study. These partners are either in a supporting role or their responsibilities in the project are considered more as business as usual. **Abis** is the main designer of the post-processing line. This line does not have any new groundbreaking features or innovations that would affect the outcome of this project. However, it is fully automated and state-of-art process. The technology itself does exist already. Abis will also construct and assemble the post-processing line for the pilot line. **JRS** is the cellulose supplier and will share it knowledge of the material. **AGH** University of Science and Technology is a University in Krakow, Poland. Their responsibility is to test and evaluate developed materials. **Arditec Association** is responsible of the final cost structure estimate and lifecycle cost analysis of the technologies.

2. LITERATURE REVIEW

In this chapter, important themes and aspects regarding innovations of NOVUM project and desired results of this paper are introduced to the reader for obtaining a sufficient knowledge to understand the phenomenon. First, 3D printing and its potential toward sustainable manufacturing is introduced. In this section the emphasis is on the potential benefits of adopting the cellulose-based material and 3D printing technology. When the benefits are known, customer value can be identified. Moreover, individual customer value propositions can be designed to simplify and concretize the allocated customer value. Customer value proposition, factors affecting it, and the design methods are described in the second subchapter. In this section the emphasis is on designing customer value propositions for business-to-business markets and novel technologies or innovations. Customer value and further customer value propositions are the starting point of commercialization process. They are the guiding principles for key resources and processes that are needed for commercializing innovations. Commercialization can have many meanings but, in this study, it refers to **launching or introducing new product to the target market**. This will be discussed in the latter part of literature review where the process, challenges, and business model of commercialization are introduced.

2.1 3D printing and sustainable manufacturing

The manufacturing concept developed in NOVUM project consist of three elements, introduced in figure 4. The first one is multi-material three-dimensional (3D) printing which have various advantages over conventional fabrication methods. Second element is fused granular fabrication (FGF) which is an emerging and unique 3D printing technology that can have a disruptive impact for the industry. Third element is cellulose-based material which is an abundant, renewable, and recyclable. Because cellulose is not thermoplastic by nature, it needs to be modified, to be able to use it in 3D printing. All these elements combined enable more sustainable manufacturing and efficient utilization of circular economy in manufacturing industry. These elements are introduced later in this section and the benefits that they provide.

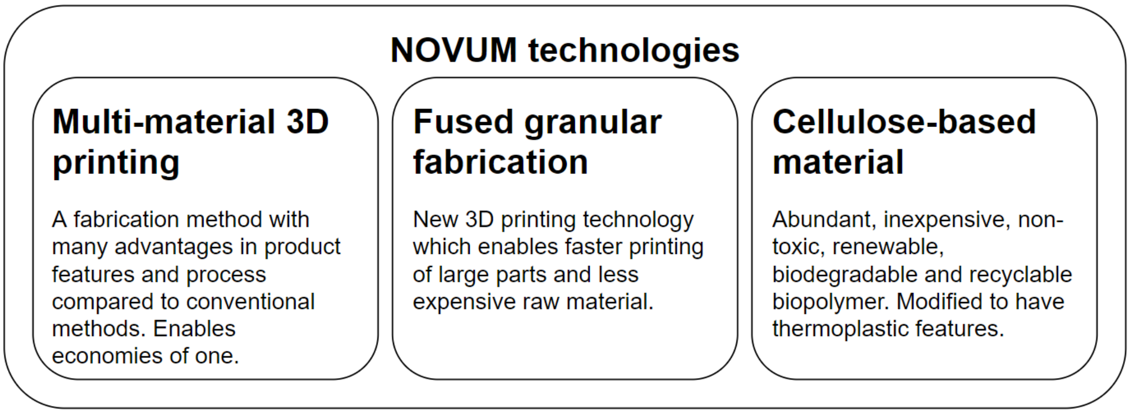

Figure 4. *Technologies developed in NOVUM project and utilized in the manufacturing concept.*

3D printing or additive manufacturing (AM) is a production technology where 3D designs can be fabricated directly from a computer-aided design (CAD) file. This way part-specific molds, tools and dies are not needed. Also, the fabrication process is more straightforward compared to conventional manufacturing processes when the process is performed with a single machine. In 3D printing, products are fabricated layer-by-layer in X-Y direction and growing towards Z direction. The materials used in 3D printing are usually polymers, ceramics, and metals. 3D printing is primary used for rapid prototyping and small batch production. 3D printing is not just a one technology but a group of rapidly developing technologies. (Bandyopadhyay & Bose, 2015; Irene & Timothy, 2013) The global market size of 3D printing products and services is estimated to grow from 16 billion US dollars in 2020 to 40.8 billion US dollars in 2024 (Statista, 2020).

There are many differences in production models of 3D printing compared to conventional production models. Traditional manufacturing industry relies on economies of scale when 3D printing enables a new production model, economies of one. It has been predicted that in the future, economies of one will complement economies of scale or even replace it in some industries. This will create more flexible manufacturing industry. When the competitive advantage of economies of scale arises from low costs, high volume and high variety, the competitive advantage of economies of one is end user customization. In the new production model, production is made locally compared to the distributed and extended supply chains of the traditional model. Because part-specific molds, tools and dies are not needed in 3D printing, the same competitive advantage of low costs in economies of scale can be reached in single unit and low volume production. (Irene & Timothy, 2013)

The basic principle of multi-material 3D printing is that a multi-material 3D printer can use several different materials in the same printing event, creating multi-material parts. The benefit of multi-material 3D printing compared to conventional manufacturing processes and traditional 3D printing is that products with differing materials can be made in one continuous step in a single machine. With conventional methods, system components are made separately and then joined together to make composite parts. The same issue is with traditional 3D printing. Components made with multi-material 3D printing have the same advantages than traditional 3D printing, but the components can have multiple materials, which adds the functionality of the product and provide possibility to create even more complex geometries. Materials with different properties (wear resistance, hardness thermal performance) can be implemented in one product in places where these material properties are most desired, thus generating property-specific areas in the product. (Bandyopadhyay & Heer, 2018)

In figure 5 are presented the most used 3D printing technologies in 2020. Fused deposition modelling (FDM) is the most used technology in 3D printing. Its advantages are affordability, accessibility, easy-to-handle process, and user-friendliness. In this technology the raw material is in filament form. The filament is heated up until it becomes molten and then extruded through a nozzle. Sometimes FDM is also called fused filament fabrication (FFF) based on the form of the raw material. The raw material needs to have thermoplastic features. The nozzle moves in horizontal directions to create one layer of the product at the time. (Zhang & Jung, 2018)

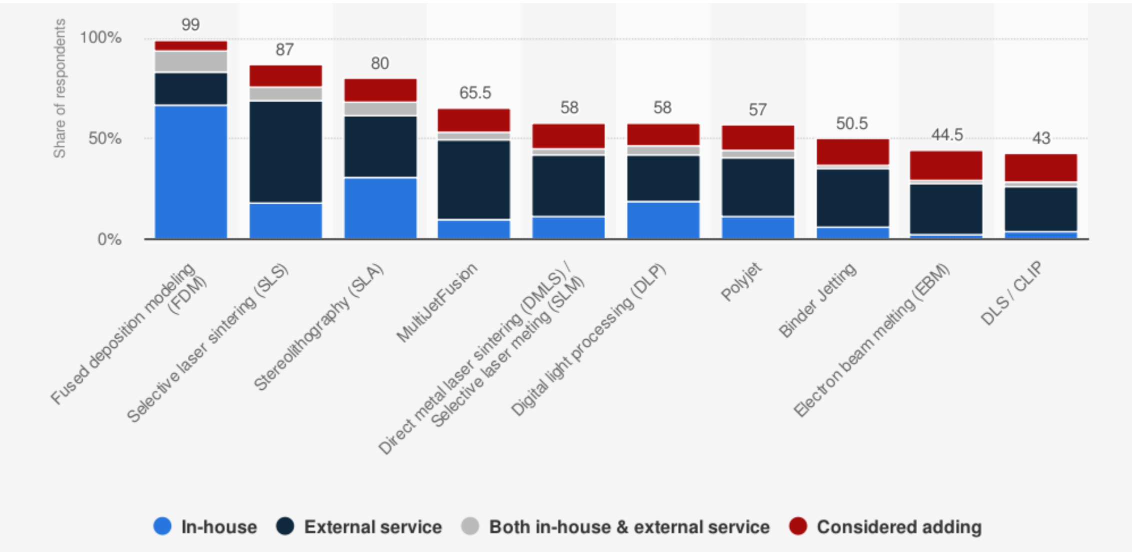

Figure 5. *Most used 3D printing technologies in 2020 (Statista, 2020).*

One emerging material extrusion 3D printing technology is fused granular fabrication (FGF) or fused particle fabrication. The basic operating principle is the same than in

FDM, but it uses granules instead of filament as feedstock. FGF generates great opportunities in the 3D printing industry. It has several advantages compared to the conventional material extrusion technology (FDM/FFF). First, the printing speed is considerably faster. FGF technology can be 6.5 to 13 times (Woern et al., 2018) or even 37 times (UPM, 2020) faster than filament-based methods. Second, the raw material cost is lower. Commercial filaments are 5 to 10 times more expensive than the polymers in granule form. This is because of the additional step in the process, filament manufacturing. High cost of filaments is most noteworthy with large-scale 3D printers which can use over one kilogram of polymer in a single print. Also, with large printing works, FFF requires changing of filament spools. Because FGF's feed tank can hold much more material, the need for manual work decreases and therefore operating costs are lower. Third, FGF makes filaments obsolete and therefore recycled polymers does not need to be processed into filament again. This enables more efficient utilization of circular economy and broader range of available material. The recycling process and tighter recycling loop is illustrated in figure 6. In conclusion, FGF technology can provide a positive environmental impact as well as operational cost benefits. (Woern et al., 2018) Hence, FGF may increase the use of recycled polymers in 3D printing.

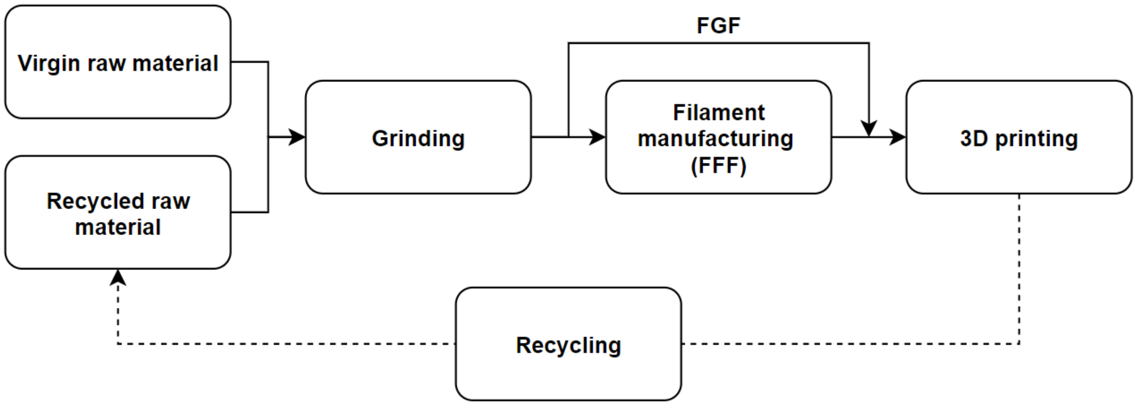

Figure 6. *Recycling process of 3D printed material (Mikula et al., 2020).*

3D printing has great opportunities what it comes to sustainable manufacturing. 3D printed products that are customized or personalized can create stronger user-product relationship and improve the attachment. This may reduce the possibility of discarding a product for psychological reasons and therefore extend the product lifetime. With 3D printing, one can design complex geometries which reduces design limitations but also have impact on sustainability. Design freedom can lead to more simple assembly lines, increased product functionality, reduced material usage and energy consumption. Lighter structures can lead to operational energy savings. Spare parts can be digitally stored and printed on-demand. On-demand manufacturing can lead to reduced inventories and may turn repairing more accessible which can increase the lifetime of products even more. Digital file of products empowers distributed manufacturing. Products can be manufactured locally which reduce emissions of transportation and shorten supply chains. Overproduction is reduced when parts are made on-demand. Repairing and recycling can also be done locally. (Sauerwein et al., 2019)

The 3D printing of certain parts can generate much of waste. The sources of waste are typically filament leftovers, overproduction, support structures and misprints. The economic and environmental feasibility of distributed 3D printing waste recycling has been studied (Santander et al., 2020) and barrier analysis been made (Peeters et al., 2019). The study demonstrates that recycling of 3D printing waste can we viable but mainly because of the high price of PLA filament. In the case study CO_2 emissions were 69.5 percent lower compared to no recycling situation. The latter study shows that the most important barriers for recycling 3D printing waste are linear economy, consumption society and high-quality demands of consumers. Homogeneous waste streams and avoiding contamination are focal factors to promote recycling of 3D printing waste. (Peeters et al., 2019)

The most commonly used materials in FDM technology are polylactic acid (PLA) and acrylonitrile butadiene styrene (ABS) (Zhang & Jung, 2018). Since FDM is the most used 3D printing technology, PLA and ABS are the most used materials in the industry. As can be seen in figure 7, nearly half of all used 3D printing material is either PLA or ABS. (Statista, 2020). PLA is made from plants such as sugarcane and corn starch, thus making it biodegradable. However, ABS is made from crude oil, so it does not have that same feature. PLA and ABS does not suit well for recycling. Product made of recycled PLA and ABS have poor material properties and thus reduces the applications. (Cress et al., 2021; Mikula et al., 2020) Also, both materials create ultrafine particle and gas emissions such as monoxide when printed. Some studies have even reported higher emissions in printing of recycled material. (Anderson, I., 2017)

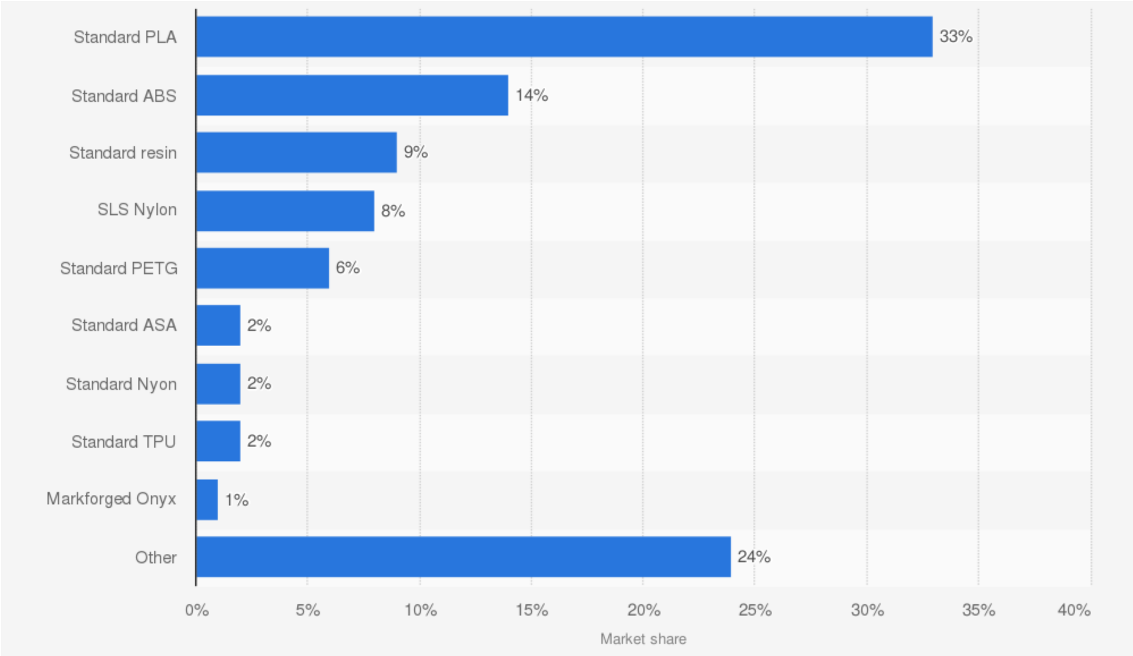

***Figure 7.** Most used 3D printing materials in 2018 (Statista, 2020).*

Novel renewable materials are receiving more attention in several industries because of the concern of environmental issues. The world's population is rising, and the use of earth's resources is increasing which is devastating from the environmental perspective. (Bandyopadhyay & Heer, 2018) National and global legislations are demanding more recyclable and sustainable materials. Biomaterials are used for replacing fossil-based materials. Cellulose is a material that could answer to this call by replacing fossil-based plastics. However, cellulose is not thermoplastic by nature, so it has to be modified. NOVUM material is a composite made of cellulose derivatives and additives. Composite materials have many benefits compared to neat polymers. Generally, they have improved stiffness and high specific strength. Disadvantages of PLA are low durability, high-temperature resistance, and UV light resistance. ABS have better material properties that PLA, but it is made from fossil-based raw material. To increase the material properties of PLA, fillers such as carbon or glass fibers, metal powders, wood, and cellulose are compounded into the material, thus possibly changing the nature of the material to non-biomaterial. However, PLA composites also have disadvantages, and therefore are not suitable for many applications. (Immonen et al., 2021)

For producing one metric ton of PLA, 11.31 tons of sugarcane or 2.39 tons of corn is needed as a raw material. For one ton of cellulose, 2.50 tons of wood is needed as raw material. (IfBB, 2020) Hence, cellulose do not compete against food production.

2.2 Customer value proposition

Customer value can mean the value for a company or value for the customer. The latter term can also be described as customer perceived value. This paper focus on the customer perceived value. The simplest definition defines customer value as what customers get if they purchase and use the offering versus what is the costs. This results in an attitude towards the offering. (Smith & Colgate, 2007)

Customer value propositions (CVP) consist of the methods that are used for helping customers to solve essential business-related challenges or for delivering value to their business. It is one of the key elements of business models in new technology product commercialization. (Pellikka, Jarkko Tapani & Malinen, 2014) CVP can also be defined as the difference between the benefits that customers receive and the price they pay in monetary terms (Wouters, 2010) or as a verbal statement that links companies competences with the needs and preferences of target customers (Rintamäki et al., 2007). The difference between business markets and consumer markets are usually that in the latter case purchasing decision is made based on aesthetics and taste when in business markets the decision is made based on functionality and performance (Wouters, 2010).

Technology push and market pull is an important comparison in the beginning of CVP development. In a case of technology push, the invention, innovation, or technology is the starting point of CVP designing process. There is already a solution ready and the CVP is built around it. Basically, here the task is to find problems to be fulfilled. The opposite of this is market pull. In this approach, there are customer problems as a starting point, which need to be solved. (Osterwalder et al., 2015)

Figure 8 illustrates how innovation creates value for the entire value chain and how that value flow back to the R&D firm as revenues. The value is based on improved processes of the technology buyer or offering superior products or services to the end user. This creates either cost reductions or higher revenue for the technology buyer. If the purchasing decision is made based on value in monetary terms the incentive to purchase depends on comparing differential price and differential value. The incentive to purchase a product or service can be demonstrated in the following way:

$$= (V_f - V_a) - (P_f - P_a), \tag{1}$$

where V_f and P_f represent the value and price of the offering of the selling company and V_a and P_a represent the value and price of the competitor's next-best alternative.

Customer will perform the transaction with the selling company if the outcome of equation 1 is a positive number. CVP can be developed by first converting the features of the offering into desired benefits for the customer. Then the benefits are converted into monetary value. (Wouters, 2010)

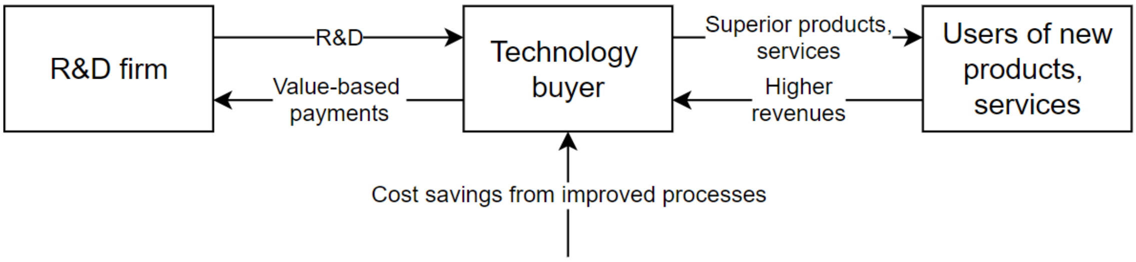

Figure 8. *Creating customer value in R&D context (Wouters, 2010).*

There are three different types of value propositions used in business markets. These are all benefits, favorable points of difference and resonating focus. In all benefits approach, every aspect of the offering that are believed to deliver benefit to the target customers are listed and presented. This approach needs the least knowledge of the target market and thus is easy to use. Because of its simplicity there are various of disadvantages with using it. First, the customer value proposition may claim benefits that the target customer does not value. This is called benefit assertion. Second, many of the benefits listed may be **points of parity** with the competing technology. Points of parity are the benefits and features that are shared with competitors and therefore are necessary to match the competitors offering. However, points of parity do not differ one's offering from the competitor's offering. Large number of points of parity will reduce the effect of **point of difference** which distinguishes one's offering from the competitors. If the value proposition shares many benefits with the second-best alternative it might lead to price competition. (Anderson, J. C. et al., 2006)

The second type of value proposition is favorable points of difference. The starting point in this approach is to recognize the alternatives for the customer to choose. The objective is to differentiate the offering from the next-best alternative. Hence, this approach requires knowledge of competitors and next-best alternative's capabilities. However, without understanding the customer's requirements and preferences this approach can lead to value presumptions. Value presumption occur when incorrect assumptions are made about features that are valuable to the target customer. The supplying company may lead to emphasize points of difference which creates little or no value to the target customer. (Anderson et al., 2006)

Resonating focus is the last one of the three types of value propositions. It is the approach that companies should prefer. In this approach, the most valuable elements for the target customer are emphasized and made superior compared to the next-best alternative. The superior performance needs to be demonstrated and documented clearly. Furthermore, the value should be communicated in a way where customer feels its business priorities are understood. Resonating focus proposition concentrates only on one or two points of difference that deliver the greatest value to the target customer. The further study and product development should be concentrated to improve the performance of these points of difference. Resonating focus value proposition might also include a point of parity when it is essential to the customer. For example, when delivering superior performance but with the same price that the next best alternative. (Anderson et al., 2006) The three types of value propositions are summarized in table 1.

Table 1. *Three types of value propositions (Anderson et al., 2006).*

Value proposition	**All benefits**	**Favorable points of difference**	**Resonating focus**
Content	All benefits that customers receive from the offering.	All favorable points of difference that the offering has compared to the next-best alternative.	One or two points of difference which will deliver the greatest value to the customer now and in future, and a point of parity if it is required.
Answers the question	Why one’s offering should be purchased?	Why one’s offering should be purchased instead of the competitor’s?	What is the most valuable of one’s offering for the target customer?
Requires	Knowledge of own offering.	Knowledge of own offering and next-best alternative	Knowledge of how own offering delivers superior value to customers compared to next best alternative.
Challenges	Benefit assertion and large number of points of parity.	Value presumption.	Requires customer value research.

There are much of uncertainty in product development projects and understanding the value of novel technologies can be difficult. It can get even more challenging in a R&D network, where the entire value chain is involving. The problems and challenges in designing CVP for novel technologies are:

- feasibility of the R&D,
- no previous data,
- substitutes, competitors, and benefits are unclear,
- applications are unclear,

- next-best alternative is unclear,
- other technologies are required,
- innovation is disruptive and
- research is public or shared in a consortium and applications are still unclear. (Wouters, 2010)

The feasibility of the R&D project may be uncertain because the development costs can vary much and even building a working prototype might be uncertain. Customer value cannot be analyzed because of the lack of data. When technology is new, the products and services based on the new technology does not exist and thus there is no previous data to be analyzed. It might be unclear what are the substituting products and services, and who are the competitors. It is impossible to compare the new product or service to the next-best alternative if these are unknown. Also, benefits of the technology may be unclear and moreover the monetary value of these benefits. (Wouters, 2010)

The next-best alternative may also be unclear when the new technology is not only a better version of a current one, but a completely different. The new technology might enable to offer considerably different and new products, processes, and services. When other technologies are also needed to construct new products, processes, and services it might be difficult to quantify the value of distinct technologies even when the value of the new offering is known. If the innovation is disruptive it can lead to great changes in the industry. It could lead to a new dominant design or industry architecture. For these kinds of innovations, the value can be impossible to conceptualize and therefore to monetize. Last, even if the research is made public or shared in a consortium the applications can be unclear. (Wouters, 2010)

Smith and Colgate (2007) have developed a framework which identifies four major types of value and five major sources of value. The framework is presented in Appendix B. The major types of value are functional/instrumental value, experiential/hedonic value, symbolic/expressive value, and cost/sacrifice value. (Smith & Colgate, 2007)

Functional/instrumental value consists of product's or service's characteristics, usefulness, and performance. Functional/instrumental values are further categorized into three key facets of value. First, appropriate features, characteristics, attributes, or functions such as quality, customization, and aesthetics. Second, appropriate performances such as performance quality and reliability. Third, appropriate outcomes such as effectiveness, operational benefits, and strategic value. (Smith & Colgate, 2007)

Experiential/hedonic value consists of experiences, feelings, and emotions that the products or services create. In business markets many organizations concentrate on social-relational values such as relationship and network benefits, responsiveness, bonding, personal interaction and developing trust or commitment. Symbolic/expressive value consists of customer attachment on psychological meaning to a product or service. For example, using certain products because of their image benefits. (Smith & Colgate, 2007)

Cost/sacrifice value consists of the transaction costs when the cost of purchase, ownership, and use are minimized. The focus here can be either minimizing economic costs, convenience and minimizing psychological costs, minimizing the personal investment of customer, or reducing the risks perceived by customer. Economic costs are the product price, switching costs, operating costs, and opportunity costs. Psychological costs are stress, search costs, psychological switching costs, and learning costs. Personal invest of the customer includes the time, effort, and energy that the purchasing and consuming process requires. Measures to reduce the risks perceived by customers are for example warranties, guarantees, and flexible return policies. (Smith & Colgate, 2007)

There are five main sources of customer value: information, products, interactions, environment, and ownership transfer. Value chain activities such as public relations, advertising, and brand management create the information. Value chain activities such as market research, R&D, new product development, and manufacturing create the products. Value chain activities such as service quality, recruitment and training, and operations create the interactions. Value chain activities such as interior design, facility management, and merchandizing create the environment. Value chain activities such as delivery, accounting, and transfer create the ownreship transfer. (Smith & Colgate, 2007)

2.3 Technology commercialization process

An effective commercialization process is required for identifying the potential benefits of innovation. In modern business environment this task is challenging because of the rapidly changing customer requirements and reducing product lifecycles. (Pellikka & Malinen, 2014) In the academic literature, commercialization has many meanings. It can refer to the product development process, launch of new product, successful marketing of the new product, or the efforts to help customer to realize the full benefits of innovation. (Pellikka, Jarkko & Virtanen, 2009) Datta et al. (2013) describes commercialization of innovations as measures required for introducing an innovation to market.

When an innovation is introduces to the market, typically only the innovators, who are the technological enthusiasts, will apply the innovation in the early stage. They represent less than 3 percent of the market. A successful commercialization requires a broader capture of the mainstream market, which consist of conservatives and pragmatists. Hence, the ability to commercialize innovations can be defined to be organization's capability to introduce new products to the market and reach the mainstream market. (Datta et al., 2013)

The main activities in commercialization process are discovery, development, and deployment. These activities can be further divided into six themes. The six themes consist of various of elements and decisions. In discovery phase, market for the innovation is recognized, followed by development phase, where the product is developed and manufactured, and last, deployment phase, where the product is sold and distributed through distribution channels. (Datta et al., 2013) The technology commercialization process including the themes and elements, and their interactions are presented in figure 9. Next, the six themes and their elements presented in more detail.

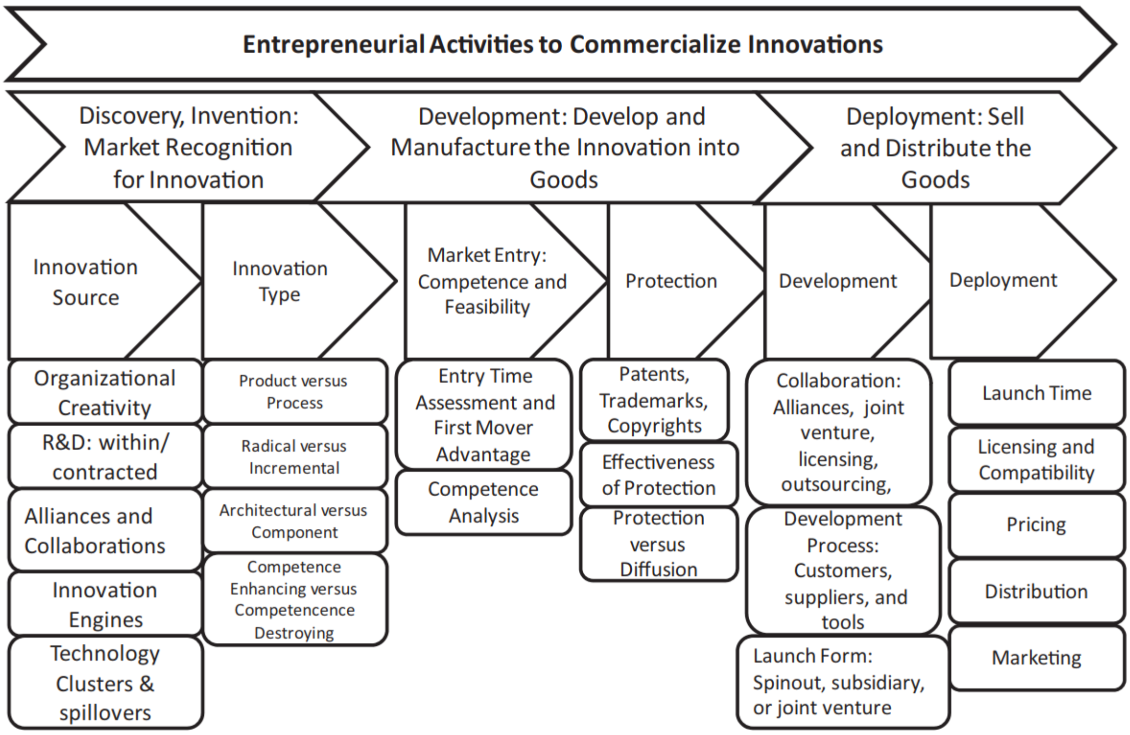

Figure 9. *Themes in the process of technological innovation commercialization (Datta et al., 2013).*

The first theme is innovation source. It describes how organizations generate innovations. For example, in NOVUM project the innovation originates from alliances and collaboration. Alliances and collaboration will help bringing organizations closer together through knowledge sharing and transferring. Networks are important for obtaining information of new product ideas. Furthermore, external sources of information complements organization own R&D activities. These R&D networks are most important in high-technology sectors where individual organizations may not have the capabilities to commercialize the innovation by themself. (Datta et al., 2013)

The innovation type can be divided in distinct dimensions as seen in figure 9. Product innovations are direct outputs of organizations when process innovations are generating improvements in the production. Radical innovations are completely different from previous innovations and result in new products or services, whereas incremental innovations are improvements in existing products and services. Architectural innovation changes the design of the whole system, whereas component innovation does not change the overall configuration of a system where it is implemented. Competence enhancing innovations are built on the organizations' existing competences, whereas competence destroying innovation is not built on existing competences but drives new competences. (Datta et al., 2013)

Market entry: competence and feasibility consist of two main activities: entry time assessment and first-mover advantage and competency analysis. Advantages of the first mover are a reputation of technological leadership, gaining brand loyalty, capturing scarce resources, exploiting buyer's switching costs, and benefits from learning-curve effects. However, there are also various of disadvantages such as high failure rates due to high R&D costs and consumer uncertainty and possibility of poor infrastructure of distribution channels, suppliers, and complementary goods availability. Second mover can exploit the R&D and marketing efforts of the first mover. They can produce the technology in lower costs and learn from the mistakes that the first mover has made. The competence analysis concentrates on identifying core competences that make the organizations product or service unique compared to other's offering in the same market. (Datta et al., 2013)

In protection theme, organizations need to consider how the innovation should be protected, how efficient the protection is, or should the innovation be left without protection for accelerating its distribution and development. Technology diffusion can encourage other organizations to promote and distribute the technology. Diffusion is most useful when organization does not have the resources or does not want to control the whole value chain, has competitors that could accelerate the development, or want to ensure that the technology becomes the dominant design. (Datta et al., 2013)

The three main elements in development theme are design and manufacture, the innovation development process, and deciding the launch form. Design and manufacture element consist of comparison between in-house and collaboration with other organizations. These collaborations through networks can be strategic alliances, joint ventures, licensing, or outsourcing. Typically, when organizations have the capabilities to develop the product and want to protect the technology and have control over the development process, they tend to manufacture the innovation in-house. However, there are multiple advantages over collaboration: cost and risk sharing, combining skills and resources, knowledge transfer between organizations, and facilitating shared standard creation. A successful innovation development process requires maximizing fit with customer requirements, minimizing time to entry, and controlling development costs. Innovation can be launched by one organization, spinouts, a subsidiary, or a joint venture. Spinout is established when a division of an organization becomes independent over the parent organization. Some of the assets, intellectual property and technology are transferred to the spinout. Subsidiary is an entity that is controlled by a parent organization. Joint ventures are used between organizations when much of resources and capabilities are needed and for sharing risks. (Datta et al., 2013)

The deployment consists of launch time, licensing and compatibility, pricing, distribution, and marketing, and thus are regarding tactic decisions of commercialization. Factors that affect launch timing are seasonal effects and business cycle, production capacity and complementary goods availability, and assessment of the effects of the launch to the existing products. Innovation can also be sold out or licensed depending on the assets required for launch, the technical compatibility issues as well as backward compatibility with previous generations. Two most common pricing techniques are market skimming and penetration pricing. With market skimming organizations ask high prices for covering the development costs swiftly or for signaling significance. Penetration pricing is used for achieving maximum market share. Organizations can utilize intermediaries or sell their products by themselves. Using distributors can accelerate the distribution of the innovation. Marketing has a great role in significant in bringing innovations to market. Decisions regarding marketing are cost, information content, reach, and target segment. (Datta et al., 2013)

In table 2 is collected and summarized different commercialization strategies or methods that can be implemented in development phase. Basically, in-house and subsidiary commercialization strategies are the only one that an organization can implement by itself. All the rest can be defined as strategies for collaborative commercialization. Collaborative strategies are used because organizations do not necessarily have all the resources and capabilities to effectively launch an innovation to the market. They may lack capacity for example in manufacturing, marketing channels, or global contacts. (Henttonen & Lehtimäki, 2017)

Table 2. *Commercialization strategies (Aslani et al., 2015; Datta et al., 2013; Henttonen & Lehtimäki, 2017; Markman et al., 2008).*

Commercialization strategy	Description
In-house	Commercialization within the organization and employing knowledge to the organization's own products and services.
Outsourcing	Outsourcing is the opposite of in-house. It is used when organizations do not have the resources and capabilities to conduct all functions in-house or want to achieve economies of scale in its core competencies.
Licensing	An organization acquires the right to utilize a particular technology.
Joint venture	Joint venture is a partnership that typically requires creation of separate entity. Two or more organizations invest in the new entity for gathering resources and capabilities together and for sharing risks.
Subsidiary	Subsidiary is a distinct entity that is controlled by a parent organization.
Strategic alliance	Strategic alliance is an agreement between two or more independent organizations to cooperate on certain business activities.
Knowledge sale	Knowledge sale is the transfer of ownership of a knowledge asset such as patent or technology.
Divestment of company units	Consist of transfer of a knowledge asset as well as the unit or division of the organization that operates with the innovation.
Spinout	Spinout is much the same than divestment of company units but here the division of organization splits off when in the previous it is sold.
Venture capital	Gathering external funding for commercialization of technological innovation.
Exhibitions	Marketing the innovation in conferences, publishing articles, and participating into international fairs of the industry.
Business incubator	An organization can utilize a business incubator who will be the key facilitator to stimulate technology commercialization. This works best in complementary innovation system.
Open science and innovation	An innovation mode where different actors such as customers and end users, co-innovate and co-create.
Contract research and consultancy	Research can be commercialized by providing access to new knowledge, enhancement of R&D, and access to talent against payment.

In chapter 2.2 Customer value proposition, different types of customer values were introduced. These customer values were functional/instrumental value, experiential/hedonic value, symbolic/expressive value, and cost/sacrifice value. Organizations seldom deliver only one type of value to the customer. However, the type of value they deliver to the customer have a significant role on the marketing strategy. (Smith & Colgate, 2007)

Organizations that compete by delivering superior functional/instrumental value follow a product-leadership strategy. They invest in value creation processes, which are related to new product development, quality, market research, and technology R&D. Continuous innovation and time to market are emphasized. Organizations that focus on delivering experiential/hedonic value follow customer responsiveness strategy. In this strategy, organizations invest in customer support technology, customer service, market research, facilities, and flexible manufacturing. Service quality, customer relationship, and customized solutions are emphasized. Symbolic/expressive value driven organizations rely on image/brand equity strategy, where they invest in advertising and public reactions, customer service and support, and product quality. They emphasize stakeholder relationships, and reward for creativity and novelty. Organizations that compete by delivering cost/sacrifice value follow operational excellence strategy. They focus on efficiency and effectiveness in purchasing, manufacturing, and distribution. Emphasize is on standardizing operating procedures and avoiding intermediate processing steps and overhead. (Smith & Colgate, 2007)

Success factors of technology commercialization are presented in table 3. The table have been collected from a comprehensive literature review by Kirchberger and Pohl (2016). The main success factors in university-industry cooperation commercialization projects are university policy and structure, followed by technology transfer strategy and researchers' individual characteristics. Technology application value means identifying potential customer value of the new technology to the end users, which is one of the key research questions in this study. Identifying customer value can help to recognize market orientation and understand the customer. This includes tasks such as identifying potential manufacturers and end customers. (Kirchberger & Pohl, 2016)

Table 3. *Success factors of technology commercialization (Kirchberger & Pohl, 2016).*

Success factor	Definition
Industry closeness	How cultural, geographic, and network proximity of technology developers to industrial companies affect technology commercialization.
Innovation culture	How general environment, values, and principles of an organization affect technology commercialization.
Intermediaries' support	How external intermediaries can help to bridge the gap between research and commercial environment.
Management techniques	How risk management, absorptive capacity, defining technology champions, knowledge management, project management, and transfer capabilities affect technology commercialization.
Networking activities	How networks between and within organizations facilitate technology transfer.
Property rights	The possibility to protect new innovations and get property rights.
Researchers' individual characteristics	Personal attributes and demographics of researchers participating in technology commercialization.
Team structure	How the background, completeness, and size affect technology commercialization.
Technology application value	How identifying potential customer value of the technology can affect technology commercialization.
Technology suitability for commercialization	How attributes of the technology can hinder or support the commercialization.
Technology transfer strategy	How the selected commercialization methods affect technology commercialization.
University policy and structure	How the policies and organizations of universities affect technology commercialization.

2.4 Technology commercialization challenges

There are much of uncertainty, problems, and challenges in commercialization of innovations. Many activities, resources, and involvement of external organizations are required to bring new products to the market. The challenges vary much between small and medium-sized companies (SMEs) and larger companies because of the limited resources of SMEs'. Traditionally SMEs lack resources from marketing and financial activities. Limited human resources can degrease propensity and ability to identify and respond to potential opportunities and threats of the business environment. SMEs are more dependent on external business know-how and networking. Also, business objectives and strategies may be unclear due to potential lack of managerial experience and expertise. (Pellikka, Jarkko et al., 2012)

Pellikka and Virtanen (2009) identified in their research the main commercialization challenges of small technology firms. The problems are categorized into three areas: environment of commercialization, marketing, and financing. The study shows that the main challenges in environment of commercialization are lack of skilled employees and support and development services provided by local institution are not available. In marketing the main challenges are acquiring of marketing resources, building of national sales and distribution channels, exploiting of market and customer information, and timing of marketing. In financing the main challenges are gathering of financial resources, insufficient venture capitalist, applying public funding takes time and resources, and the need for financing is rapidly changing. (Pellikka & Virtanen, 2009)

Aarikka-Stenroos and Lehtimäki (2014) identified six commercialization challenges regarding radical innovations. These challenges and their interactions are presented in figure 10. The challenges cannot be solved and decided at the same time because otherwise important information is missing for solving the next challenge and thus solving commercialization challenges is a step-by-step process. This process always starts by choosing the correct strategy. Only the fourth challenge, acquiring support from stakeholders and the ecosystem, and the fifth challenge, overcoming adoption barriers and facilitating the adoption can be solved in parallel. (Aarikka-Stenroos & Lehtimaki, 2014)

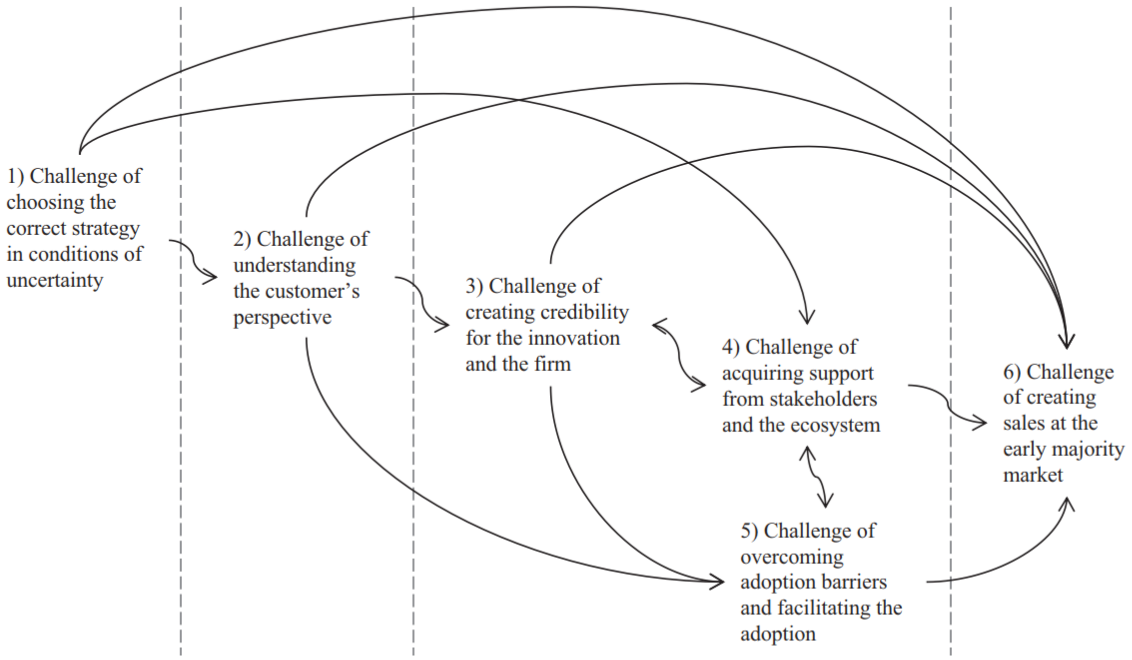

Figure 10. *Commercialization challenges and their linkages (Aarikka-Stenroos & Lehtimaki, 2014).*

Much of uncertainty arise in innovation commercialization processes and therefore it can be difficult to design a feasible strategy. Organizations may not have all the information and experience of the market that are needed for designing the initial strategy. After the launch of the product or service, often the strategy needs to be modified, which can lead to changes in the offering, target segment, positioning, customer value proposition, or business model. Interacting early with stakeholders such as customers, distributors, complementors, and legislators can help organization to gather market knowledge and therefore creating a more feasible strategy. (Aarikka-Stenroos & Lehtimaki, 2014)

The second challenge arise when organizations do not understand the customer benefits. The customer value proposition should not be designed from the technology perspective. Organizations tend to focus on the technology and marketing and therefore build their sales efforts around the technology's benefits. It is important to recognize the customers' perspective on benefits and value potential, in which context customers are using the technology, and their preferences. (Aarikka-Stenroos & Lehtimaki, 2014)

The third challenge is creating credibility for the innovation and the organization. This challenge arises when the product category is new, and the supporting ecosystem is not ready. Typically, these products have also many rivals with novel technologies, which have the same benefits for the customers. Organizations try to increase their credibility by partnering and networking, validating the innovation and its benefits through scientific testing, customer references, customer education, and exploiting existing brands. (Aarikka-Stenroos & Lehtimaki, 2014)

When commercializing radical innovations, organizations need to either enter and modify an existing ecosystem or create an entirely new one. Therefore, challenge of acquiring support from stakeholders and the ecosystem arises. Distributors and regulators were identified to be the most crucial stakeholders in the ecosystem. (Aarikka-Stenroos & Lehtimaki, 2014)

The fifth challenge is overcoming adoption barriers and facilitating the adoption. Radical innovations might require changes in customers' as well as other stakeholders' attitudes, behaviors, or processes. The first step of organization is to identify these adoption barriers. Then, these adoption barriers need to be overcome by preparing the markets. Actions to overcome these barriers are education, instruction, awareness building, and encouraging customers to switch from the old technology. However, these activities consume much of valuable resources. One strategy is to collaborate with lead users. (Aarikka-Stenroos & Lehtimaki, 2014)

The last and sixth challenge is creating sales at the early majority market. Challenges in sales generation can force the organization to review its commercialization process and make changes in strategy. Specific difficulties here are when organizations need distribution partners and investors to launch the innovation, but these stakeholders require evidence of sales and market potential first. Also, although an organization succeed in early market, they may struggle in reaching the early majority market. This means that organizations need to apply different approaches when they try to capture sales from different market categories. (Aarikka-Stenroos & Lehtimaki, 2014)

In this study the commercialization refers to launching new product to the target market. Therefore, the reasons for market success/failure of the innovation once it has been launched to the market is discussed next. The relevant performance indicators when evaluating market success/failure are customer acceptance and financial performance. Typically, these dimensions are interrelated but not in all cases. In their study, Chiesa and Frattini (2011) identified two ways how to influence customer acceptance in high-technology markets. First, ensuring support from the players in the innovation's adoption network. This is emphasized when commercializing systemic innovations. Systemic innovation requires a considerable change of the other components in the system. In the other hand, autonomous or stand-alone innovations does not have this requirement. Therefore, many various stakeholders need to be persuaded to support the innovation and their actions have greater influence on the success. Second, affecting the attitudes of early adopters after the first purchase and use. This will trigger a positive or negative word-of-mouth marketing effect towards later adopters. This have a greater influence on radical innovations because the uncertainty of customers' consumption is much higher. (Chiesa & Frattini, 2011)

They suggest several recommendations how to ensure extensive supports from the adoption network:

- Establishing long term strategic partnership with critical stakeholders in the adoption network before the innovation is diffused into the majority of the target market.
- Out licensing the technology to the main competitors and complementary product developers.
- If a software is included, selling its development tool at low price or free of charge.
- Clear positioning of the innovation.

For affecting the post-purchase attitudes of early adopters, they suggest measures presented below:

- The innovation is launched after the product configuration is complete.
- Early preannouncement if the product configuration at launch is complete.
- Early adopters are proactively targeted.

- Positioning of the innovation as a groundbreaking technology.
- At launch, the product includes critical functionalities for the early adopters, and they are working perfectly.
- Simple configuration with only few additional functionalities to the core functions.
- The product includes all the functionalities communicated during the preannouncement campaign.
- Focus on the technical capabilities and degree of sophistication of the innovation during the preannouncement campaign. (Chiesa & Frattini, 2011)

2.5 Business models in commercialization process

Business models involve various business partners. All actions, which the partners involved in the business model conduct, must be aligned to effectively exploit their competences and technological assets in the commercialization process. Partnering up and cooperating in the stages of commercialization process can significantly reduce the time to market and expenses, increase profitability, enhance innovation capability, generate greater flexibility in R&D, expand market access, and create new business opportunities. However, customer involvement in the commercialization process may lead to allocating limited resources too narrowly and hinder commercialization. (Pellikka & Malinen, 2014)

Business models consist of four elements that together create and deliver value to the customers. The four elements and their linkages are presented in figure 10. The most important one of the elements is customer value proposition. CVP was discussed in more detail in chapter 2.2 Customer value proposition. It describes the customer's problem that needs solution. It is the starting point of creating business model and therefore the foundation that will lead the design of the other elements. (Johnson et al., 2008)

Profit formula describes how the organization creates value for itself while the customers obtain the value of the CVP. Profit formula includes for example revenue model (expected revenue), cost structure (cost of the key resources), margin model (profit), and resource velocity (utilization of resources, inventory, and assets). (Johnson et al., 2008)

Key resources are the key assets and elements required for creating and delivering the CVP to the target customer. Generic resources that do not differentiate organizations from its competitors and therefore do not generate competitive advantage are not required here. (Johnson et al., 2008) This is consistent with the principals of designing CVP (Anderson et al., 2006).

Key processes are the processes that enable organization to create and deliver the CVP to the target customer. These processes may facilitate organization to obtain recurring sales. Key processes include processes (designing, product development, sourcing, production, marketing, training, and service), rules and metrics (lead times, supplier terms, and credit terms), and norms (opportunity size needed for investment and approach to customers and channels). (Johnson et al., 2008)

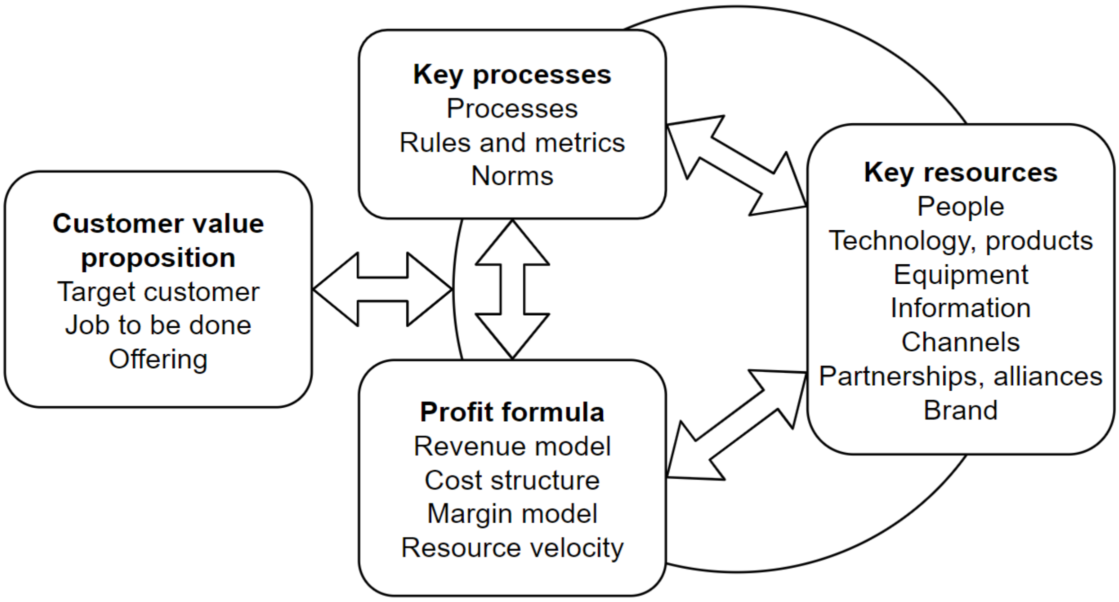

Figure 11. *Elements of a business model (Johnson et al., 2008).*

Major changes in any of these four elements of business model affect each other. This may lead to changes in the whole business model, and especially if the CVP changes. (Johnson et al., 2008) A study made by Pellikka and Malinen (2014) noticed that many small technology companies emphasized value creation to customers and understated value capturing (profit formula) in their business models and therefore companies were unable to realize the potential value of the innovation during the commercialization process. (Pellikka & Malinen, 2014)

3. RESEARCH METHODOLOGY AND MATERIALS

In this chapter, the research methodology and materials are introduced to the reader. This study will be conducted with qualitative research methods. There has been argues how the difference between qualitative and quantitative research are defined. However, the most straightforward difference between these methods is that quantitative methods are based on numbers or quantities when qualitative methods try to explain the phenomenon with other findings. (Hirsjärvi & Hurme, 2008) Quantitative methods could not be used in this research because research problem is tried to be solved using opinions and viewpoints of case project partners.

The research process is as follows (figure 12): In the first phase, the study is planned. The study starts with an idea of research and then, a well-defined research plan and problem are conducted. The objective and scope of the study is defined, research methods are chosen, and the study is scheduled. The second phase is to introduce to the topic. What have been studied before and introducing to the research case. Third phase is the data collection. In this study, the main data collection method is semi-structured expert interviews, but also secondary data collection methods literature and a broad archive of case project documents were used. Fourth phase is data analysis. A framework for analyzing the data and achieving the research objectives was created. The last phase is the reporting phase, although writing is occurring in every phase of the process. (Kallinen & Kinnunen, 2021) The case in this paper is given because this study was commissioned by VTT. The case project was introduced in the chapter 1.4 The ecosystem of the study. The chosen organizations are the main beneficiaries of the R&D results in the case project.

Figure 12. *Qualitative research process (Kallinen & Kinnunen, 2021).*

In the chapters below, data collection and data analysis phases are introduced in dept to the reader. Also, the research is evaluated in the last subchapter.

3.1 Data collection

Qualitative research methods are used for achieving the objectives of this study. For the primary data collection method was semi-structured qualitative expert interviews chosen. Interviews were chosen to be the main data collection method because the aim is to get different opinions how the commercialization should be conducted. The idea behind semi-structured interviews is utilization of tape recorder. This way a large quantity of data can be documented easily. (Kallinen & Kinnunen, 2021) Open-ended questions are created in advance, so that interviewees can answer in their own words and the questions are the same for all (Hirsjärvi & Hurme, 2008). The difference with fully structured interviews is that the response alternatives are also created beforehand. Precise and carefully generated questionnaires are useful in expert interviews. (Kallinen & Kinnunen, 2021) Expert interviews are used when collecting data that cannot be acquired elsewhere. Experts have special know-how about the researched topic that no one else have or are in charge of the process. (Hyvärinen et al., 2017) In this case, interviewed experts are the representatives of the organizations in the case project NOVUM. They represent their organization in the project and therefore have the best knowledge on the topics. Although questionnaires were created in advantage the aim was to create conversation around the topics, thus having also features of theme interviews (Kallinen & Kinnunen, 2021).

Questionnaires were sent to the interviewees a week before the interview so the representatives could get to know the questions and discuss them internally. The questions asked from OEM and R&D partners were different but were related to the same themes and topics. The questionnaire for OEM partners is presented in Appendix C and for R&D partners in Appendix D. In the table 4 below are the interviews and their information presented.

Table 4. *Interviews.*

Organization	Number of interviewees	Language	Date
Meyer Turku	Two	Finnish	26.3.2021
Hitachi ABB Power Grid	One	English	29.3.2021
Centro Ricerche Fiat	Two	English	31.3.2021
Brinter	One	Finnish	7.4.2021
VTT	Two One	Finnish Finnish	8.4.2021 19.5.2020

All the interviews were conducted online via video conference due to the Covid-19 and the long distances. One and a half hours were allocated for each interview. The interviews were recorded for creating undisturbed conversation and later analysis purposes. Although NOVUM project is a public R&D project the interviewees are kept anonymous.

Secondary data was also utilized and collected from project documents and theoretical background. Secondary data is data that were initially collected for other purposes. (Saunders et al., 2019) Especially when the benefits and the characteristics of the technologies were analyzed, the literature review could provide previous and general knowledge of the topic.

3.2 Data analysis

Qualitative research analysis is defined to be compressing the data and processing it into a theoretical form. There is not any universal pattern or model how the analysis is conducted. However, the main task is to generate something substantial from little and dig into the data. (Kallinen & Kinnunen, 2021) The data analysis in this research was done utilizing thematic analysis. Thematic analysis is a systematic, flexible, and accessible approach to analyze qualitative data. The first phase of the data analysis is to become familiar with the data. This was done by producing transcripts of the interviews. In this phase the recorded interviews were converted into literal form. Data familiarization is important in research because it will increase the interest in meaning, recurring themes, and patterns in the data. (Saunders et al., 2019) In the data analysis perspective, the factual content of the interviews was the main interest. Therefore, some of the content was filtered out in this phase already.

The next step of the analysis when the transcriptions are done, is coding (Saunders et al., 2019). Coding is broadly exploited basic method for analyzing qualitative research. In this method data are joined together and sorted out into categories or themes based on similar characteristics of the data. (Kallinen & Kinnunen, 2021) Then the analysis continued by seeking similarities, extremes, and divergent events (Hirsjärvi & Hurme, 2008). In this phase, the data is in a table form. The coded data is presented in table form and then literally opened up in the text in chapter 4. Results. Next, this coded data was utilized for creating the data analysis that will have the answers to the research problem. In this phase, the categorized coded data is again seen as a unity, so that the phenomenon can be analyzed in-depth. In the analysis and discussion, the phenomenon is tried to be described in thick matter, which means that not only facts are presented but also the phenomenon is described as deeply as possible. (Hirsjärvi & Hurme, 2008)

As stated in the literature review, an effective commercialization process is required for identifying the potential benefits of innovation. Therefore, a theoretical framework for achieving the objectives of this study was created. The framework is presented in figure 13.

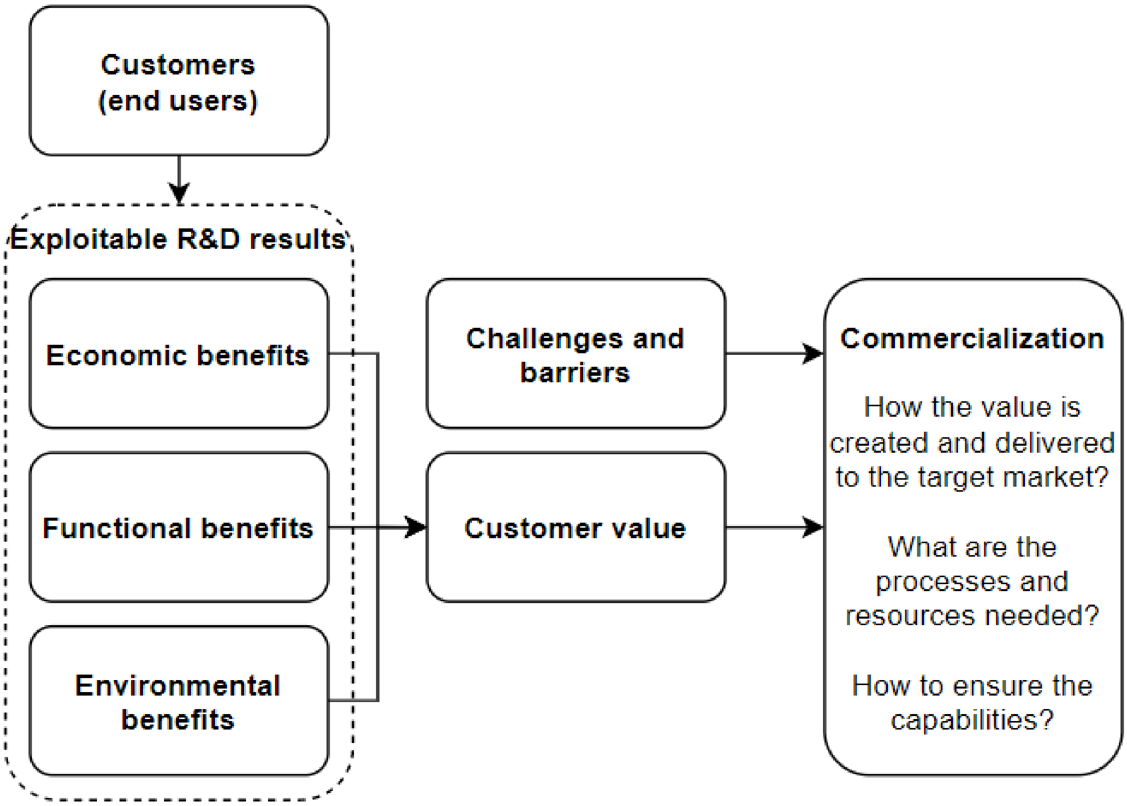

Figure 13. *A theoretical framework for commercializing R&D results.*

This framework will be the foundation that will guide the analysis and discussion of this study. First, with the help of the coded data collected from the interviews, exploitable R&D results are identified. Second, the benefits identified in the literature review and interviews are interconnected with the exploitable R&D results to identify and determine customer value. However, the main input in identifying customer value are the individual interviews where end user specific information about benefits are obtained. To gain distinguishable, shorter, and more controllable instrument for commercialization, distinct CVPs for each end user are designed. Third, general and case specific challenges and barriers in technology commercialization are identified with help of literature and interviews. Last, CVP, challenges, and barriers will guide the commercialization. In this last step of the framework, key resources and processes for creating and delivering the

CVP to the target market are identified and measures for ensuring these capabilities are proposed. Also, countermeasures for identified challenges and barriers are proposed.

3.3 Evaluation of the research

The terms reliability and validity are generally used when evaluating research. Reliability means that when studying the same person, the outcome is the same every time. Or in other words repeatability of the results of the research. The term validity has multiple purposes. It can evaluate if the results from coming research can be predicted from the results, is the research covering the desired matters, or can the results be generalized for a broader use. However, these terms may not be feasible in interview-based research because the circumstances are unique. (Hirsjärvi & Hurme, 2008) Therefore, the results cannot be generalized for broader scope. In this study it means that the results are valid only in the case project NOVUM. Saunders et al. (2009) states that more usable criteria for evaluating qualitative research are dependability, credibility, transferability, and authenticity (Saunders et al., 2019).

Quality control is important when conducting research. One aspect for achieving high-quality results is creating good structure of the interviews. (Hirsjärvi & Hurme, 2008) Therefore, the questionnaires went through review rounds where they were evaluated and modified before sending them. Coding of the data was fairly easy to conduct because same kind of questions were asked from all the interviewees. The results of the interviews were sent to the interviewees to ensure the authenticity of content before the analysis and discussion was conducted.

One limitation of this study is the number of interviewed case organizations. Because the organizations are participating in a radical R&D project like NOVUM, it can be said that they are innovators and do not represent the mainstream market. As said in the literature review, the launch is stated to be successful when it can reach the mainstream market. Therefore, a broader market study is needed, where the preferences of early adopters are studied.

4. RESULTS

In this chapter, the data collected in the interviews are presented as the results of this study. NOVUM project is categorized into four different layers to get more detailed overview and to cover all the benefits that partners are seeking. These layers are illustrated in figure 14. The first or core layer focus on the benefits that are sought from the technology level. Second layer discusses the technologies as one, or in this case the manufacturing concept. Third layer is the value chain level where the benefits obtained from other partners are discussed. Last layer is the project level where the objectives and gains of each partner are discussed. The benefits obtained from the technology and manufacturing concept are quite much the same and their performance are interdependent. Therefore, these benefits are presented as one.

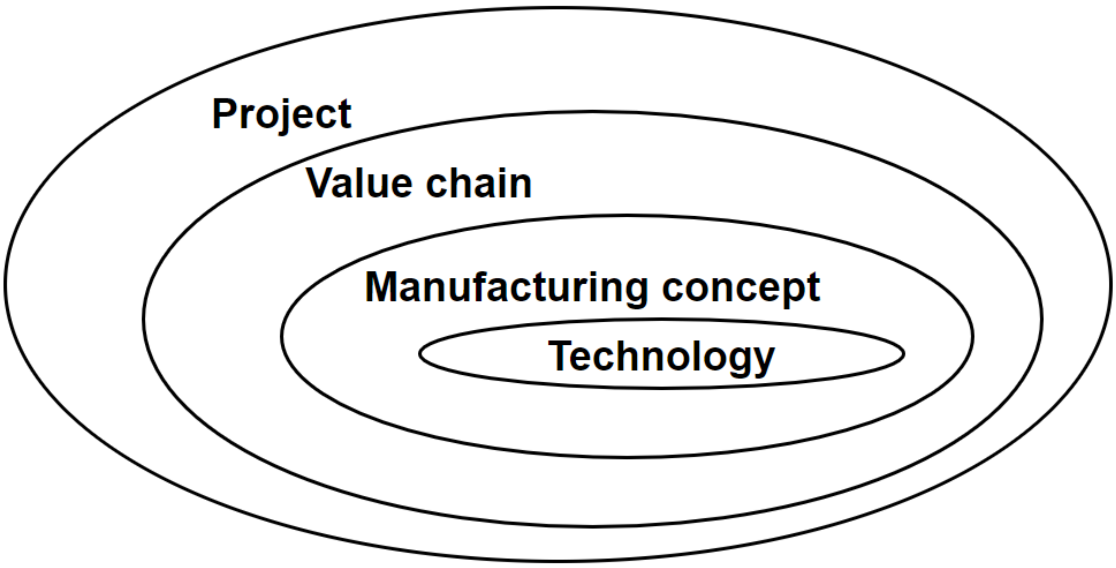

Figure 14. *Different layers in NOVUM project.*

When partner’s objectives in each layer were defined, the exploitation of the results was studied. In this part, the partners were asked how each will utilize the technology and for which products. In the latter part of this chapter, first, the potential challenges and barriers that were identified during the interviews are presented, followed by the drivers for exploitation.

4.1 Benefits from technology and material - OEM partners

In this chapter the benefits that the original equipment manufacturer (OEM) partners are seeking from the developed technology and material are presented. In this study, OEM refers to the manufacturer of the final product and under whose brand the product is sold to the customers. The benefits sought by different partners in the technology level are further divided into three different values by their nature. The benefits are connected into the value where they have their greatest impact. The values are economic, functional, and environmental as presented in figure 15. These distinct values are created with help of Smith and Colgate (2007) framework introduced in the literature review and fully presented in Appendix B (Smith & Colgate, 2007). The values are modified to suit better the operational environment of this study and business-to-business markets. Experiential/hedonic value and symbolic/expressive value are replaced with environmental value, which is emphasized in this R&D project. Also, in business-to-business markets, value dimension that are more objective and utilitarian (functional/instrumental value and cost/sacrifice value) are emphasized over subjective and hedonic value dimension (experiential/hedonic value and symbolic/expressive value) (Rintamäki et al., 2007; Smith & Colgate, 2007; Wouters, 2010). When business-to-business organizations evaluate experiential/hedonic values, they focus on social/relational values which will be covered on the value chain layer of the project (see figure 14) (Smith & Colgate, 2007). In some cases, the boundaries between different values can be unclear. The benefits identified have a great impact on each other and thus in most cases one benefit will originate from another benefit. The results are introduced in the order where the partners were interviewed.

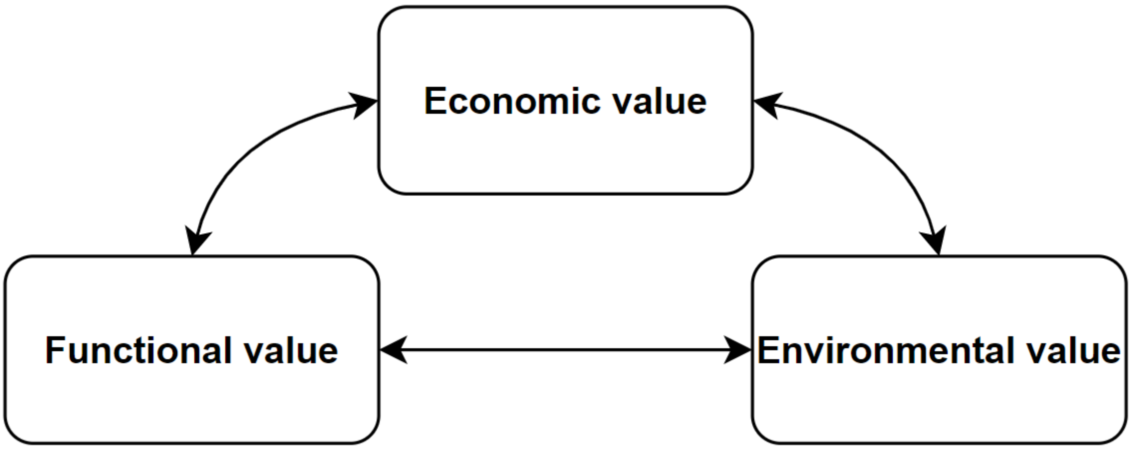

Figure 15. *Classification of customer values.*

The economic values that OEM partners are seeking are presented in table 5. All partners are seeking for reductions in their production costs. However, the fundamentals and how these production cost reductions are generated are different. The main common factor is that 3D printing makes molds obsolete, thus reducing costs relating to molds. Mold costs consist of operating costs when the molds are produced and the managing costs for storing them. This will also lower the investments needed for new components because molds tie up capital before the first transaction. Meyer Turku's (MT) and Hitachi ABB Power Grids' (Hitachi ABB PG) current production is extremely labor intensive. 3D printing could generate reductions and therefore benefits in labor costs.

MT stands out from the other partners by seeking benefits in installation costs. In the outfitting stage there are many works been done onboard the vessel which takes more time. MT's objective is to have the design freedom to be able to produce components that are simple and light to install, thus reducing installation time and therefore costs.

The unique benefit that Hitachi ABB PG is seeking is the energy savings in their process. Replacing the conventional method with 3D printing, they can eliminate the time and energy consuming drying phase in their manufacturing process. Compared to the other partners the reduction of mold storing costs was emphasized by Hitachi ABB PG. Every year hundreds of new molds are designed and fabricated. Furthermore, some of the new molds are used only for producing a few components.

For Centro Ricerche Fiat (CRF) the economic values are not the main drivers, but they still identified a few distinctive factors. In their industry the spare part management is a great cost for a company. Car manufacturers need to assure that spare parts are available for some time after the end of production of a specific car model. If new components are manufactured using NOVUM material, they can use a digital warehouse and fabricate new spare parts locally and for demand. There would also be cost reductions in coating costs, if NOVUM material will have aesthetic features that would eliminate the need for coating. Especially CRF is preparing itself for future plastic banning legislation and requirement for using recyclable and bio-based materials. This is crucial for CRF because it can take several years to redesign components and to acquire the capabilities needed. More about the changing legislation is introduced in the chapter 4.7 Drivers for exploitation.

Table 5. *Economic values sought by OEM partners.*

Meyer Turku	Hitachi ABB Power Grids	Centro Ricerche Fiat
• Reduced manufacturing costs. • Reduced labor costs. • Reduced installation costs.	• Reduced labor costs. • Energy savings. • Reduced cost of storage.	• Reduced manufacturing costs. • Lower investment for new components. • Reduced logistic costs. • Reduced coating costs. • Prevention of plastic banning fees and costs.
Economic value		

The functional values that OEM partners are seeking are presented in table 6. The functional value that is shared between all OEM partners is the design freedom which can help them to optimize their products, fabricate complex structures or personalize their products. MT and Hitachi ABB PG are also trying to reduce the lead time of manufacturing. MT could replace damaged components and products faster to the customers. In transformer business, delivery time can be a crucial factor to win tenders in cases of transformer failures.

In long-term there are a few of unique benefits that MT is seeking. These are weight reductions, vibration damping and soundproofing. Weight reductions will help in installation process but also, if utilized in greater scale, to reduce the mass of the whole vessel. Weight reductions of the vessel could help to reallocate weight to other value generating functions for example adding an extra jacuzzi on the deck or generate operational cost reductions or in other words, savings in fuel cost. Also, weight reductions on the upper decks increase the stability of the vessel. These benefits are dependent on the development of fibrous foam printing technology and technology exploitation in very large-scale.

The distinctive functional values of Hitachi ABB PG are reduced storage for molds and the capability to redesign its transformers. By optimizing the shape of the components, they could improve the performance of their current and coming transformers. For example, improving oil circulation or the size of transformers.

Functional values that NOVUM material could provide to CRF are the unique material properties and a broader range of material in their material portfolio. These material properties still need to be studied more but they could be features like softness, low gloss, scratch, UV resistance and so on. Functional values sought from 3D printing technology are rapid prototyping and spare part production and management. These benefits are well covered in the literature.

Table 6. *Functional values sought by OEM partners.*

Meyer Turku	Hitachi ABB Power Grids	Centro Ricerche Fiat
• Reduced installation time. • Reduced lead time. • Shorter value chain. • Reduced mass of the vessel or weight reallocation. • Fabrication of complex structures / design freedom. • Broader range of materials. • Vibration damping and soundproofing.	• Reduced labor time. • Reduced cycle time. • Reduced storage. • Design freedom. • Optimizing and improving performance of the transformers.	• Prototyping in early phase. • Spare part production. • Personalization. • Broader range of materials. • Aesthetic material properties. • Other material properties.
Functional value		

The environmental values that OEM partners are seeking are presented in table 7. MT and CRF both stated that capability to offer more sustainable materials to the customers is an important environmental value. At present, the insulation components are made from cellulose, so they do not provide the same benefit to Hitachi ABB PG. Using bio-based and recyclable materials in their production, CRF could improve the overall sustainability. In Hitachi ABB PG's case the environmental impact from eliminating the drying phase is considerable and it can be emphasized even more because coal is the dominant energy source in Poland. The current production also consumes a significant amount of water and therefore generates almost as much wastewater. The new manufacturing concept will help Hitachi ABB PG to reduce these issues. Local recycling and reduced waste generation were also identified as an environmental value by MT and Hitachi ABB PG. With 3D printing and fused granular fabrication (FGF) technology local recycling would not be limited on NOVUM material but all 3D printable materials could be recycled. Especially when cruise vessels are refitted the material could be circulated more efficiently. However, it was stated that the recycling needs to be studied more.

Table 7. *Environmental values sought by OEM partners.*

Meyer Turku	Hitachi ABB Power Grids	Centro Ricerche Fiat
• Use of environmentally friendly materials. • Reduced waste generation. • More efficient recycling. • Local recycling.	• Reduced energy consumption. • Reduced water consumption and wastewater generation. • Reduced waste generation. • Recycling of waste / local recycling.	• Sustainability. • Material from renewable source.
Environmental value		

The main drivers for MT are the functional and environmental values. Mainly the design freedom and use of environmentally friendly materials. With these values they try to stand out from competing shipyards and improve their competitive advantage. Main drivers for Hitachi ABB PG are a combination of cost reductions, shorter cycle time and more sustainable production. For CRF the main drivers are sustainability and new green materials but also cost reductions and personalization when using 3D printing technology.

4.2 Benefits from technology and material - R&D partners

In this chapter the benefits from NOVUM technology, material and pilot line are discussed more broadly and over the scope of OEM partners. These are the benefits that Brinter and VTT identified as the research and development (R&D) partners. They have carried the main responsibility for the R&D activities in this project. VTT as the material developer and Brinter as the 3D printing technology developer. The benefits are divided into three different values as in the previous chapter (see figure 12) and presented in table 8.

It was emphasized that some shapes and structures can be difficult or even impossible to fabricate with conventional technologies such as injection molding or handwork. Also, using conventional manufacturing technologies the cost per unit is higher when producing small batches. Hence, some components are not feasible to fabricate in other technologies than 3D printing. The NOVUM concept can also enable more efficient circular economy. This is because the material is reusable, and the NOVUM 3D printing technology can use granules or grinded raw material. There is no need for filament production process and the material is immediately reusable after the grinding. New business opportunities could occur because NOVUM technology is suitable for other applications than just the ones proposed in this project. Developing oneself and using green materials will also have image benefits as a pioneer, which can later be used in marketing purposes.

3D printing enables more efficient demand driven manufacturing because there is no need for stock of components. Components are fabricated on demand. Local manufacturing is more suitable for 3D printing because transportation is not needed when products are stored in digital warehouse. The production process is more simplified when stages from fabrication process are eliminated and the whole fabrication is done with one machine. One of the key benefits of the pilot line is the automated process. Automated process will ensure better and constant quality. Multi-material printing was identified by Brinter as one of the main benefits obtained from NOVUM technology. At the moment, products made from multiple materials cannot be fabricated with other technologies or at least the same time.

Using fibrous foam printing technology, products can be made porous and lightweight. These products have also good heat insulation and vibration damping features. Integrating multi-material and foam printing, one can produce sandwich-structured composites where the foam is used as the filler. When the product design is optimized and the capabilities of 3D printing have been implemented in the design process, material consumption can be reduced in the fabrication process. One focal environmental value that an organization receive when replacing fossil fuel-based plastics with NOVUM material is that it will increase the use of recyclable and bio-based materials.

Table 8. *Benefits identified by R&D partners.*

Economic value	• Individual part and small batch production are very expensive with other manufacturing technologies. • Enables circular economy. • New business opportunities. • Image and marketing benefits.
Functional value	• Demand driven manufacturing. • Local production. • Simplified production process. • Automated process ensures better and constant quality. • Multi-material printing. • Porous and light structures.
Environmental value	• Reduced material consumption. • Increase the possibility to use of recyclable, bio-based materials.

4.3 Benefits from project’s value chain

In this chapter, the benefits that each partner are seeking from the value chain level are presented. The benefits that the OEM partners are seeking are gathered in table 9 and the benefits sought by R&D partners are in table 10. Networking, acquiring know-how by knowledge sharing and material testing were the connective factor for all the partners. For example, Brinter predicts that bio- and cellulose-based materials will be more commonly used in the future and thus want to build their expertise on it. Also, identifying future development projects or activities was mentioned often in the interviews. However, there are some focal differences between partners objectives in the value chain level.

MT and Hitachi ABB PG are focused on gaining know-how and building their own capabilities. Hitachi ABB PG highlighted that EU funded consortium have more power than smaller scale R&D projects. For example, the awareness of the project is higher, and it is easier to get external partners to be involved. In this project the material testing by external partners have been easy because of the power of the consortium. It is also important that the whole value chain from material development to the final production is involved in the project.

CRF is determined to find solution for their challenge of the future. CRF's goal is to find new material formulations that are suitable for future legislation. Therefore, one of the key tasks in this project is to study if there is a material compounder that can supply NOVUM material in large quantity. Other approach is to provide NOVUM material for CRF's current suppliers for testing, and to find out if they can supply the material. Also, CRF mentioned that because Brinter as a technology supplier is involved in the project, the value chain for 3D printing is well covered.

Table 9. *Benefits sought from the project value chain by OEM partners.*

Meyer Turku	Hitachi ABB Power Grids	Centro Ricerche Fiat
• Know-how about 3D printing and novel materials. • Networking for future development projects.	• Know-how, different point of views. • Networking and building relationships with partners. • Future activities / development projects. • The whole value chain is covered in the project. • Power of EU funded consortium.	• VTT can provide new materials and formulations that can be tested by CRF. • Finding a material supplier/compounder. • Integrate parts from NOVUM's value chain into CRF's. • Technology supplier.

For Brinter and VTT as R&D partners it is important to get information about the final products from OEM partners. It was mentioned that R&D activities proceed better in an ecosystem environment where there are also the end users involved. Inside information that cannot be acquired anywhere else can be used for creating more suitable and practical products. Products can be tested directly by the end users and when there are several potential end users involved, the risks of the project are mitigated.

For VTT it is also important to get information from raw material supplier about how the demand is evolving, what are the needs of their customers and how the technology and material requirements are developing. Networking and cooperation broader than NOVUM consortium are great benefits when partners can collaborate with stakeholders from other partners network. In this project, this have happened several times. For VTT as a research organization it is important to share its capabilities with partners because every project where VTT is involved is a marketing channel. Therefore, not only the results will determine if the project is a success but all the communication and events that have taken place.

Table 10. *Benefits sought from the project value chain by R&D partners.*

Brinter	VTT
• Networking and knowledge sharing. • Research and development activities proceed better in ecosystem environment. • End user participation which provide important information about final products and from different perspectives. • Developed products can be tested. • Several end users mitigate risks. • Future cooperation.	• New and different perspectives from several different companies. • Inside information from the end users about their current products. • Information about material properties that are the most important. • Raw material supplier provides know-how and information about demand and future technology and material requirements. • Networking broader than the consortium. • Cooperation. • Identifying future research projects. • Value chain as a marketing channel for VTT's capabilities.

4.4 Benefits from the project

In this chapter the benefits that each partner is seeking are discussed in the broadest level. These are the benefits that partners are obtaining from the results of this project. To obtain these benefits, the exploitation of NOVUM project results needs to be successful. Results in this chapter have also the biggest dispersion between partners and thus for each partner the benefits sought from the project is a unique unity. The benefits regarding OEM partners are presented in table 11 and R&D partners in table 12.

Competition on the cruiser industry is tough and because MT cannot compete with price against low-cost shipyards in Asia, it needs to find other sources for competitive advantage. Being able to produce something that its competitors are not capable is an opportunity for obtaining competitive advantage. Having the capabilities to offer novel products with complex shapes could help standing out from competitors. MT have identified that 3D printing is a technology that can offer this kind of capabilities for it. In the long term, multi-material 3D printing integrated with capability of fibrous foam printing can have great impact on reducing the overall weight of the vessel. Weight reductions could be exploited by offering its customers more functions that normally would not be possible because of the additional weight. This would be a disruptive technology and therefore considerably enhance the competitive advantage of the shipyard. However, to obtain any significant weight reductions, the method should be used in large scale and therefore many obstacles such as fireproofing need to be overcame. Cruise industry have had troubles with its image because there have been for example, scandals relating to managing wastewaters and how efficient it is to operate such large vessels just for fun. Using a sustainable material and decreasing waste generation in the manufacturing would provide to MT an opportunity to offer for its customers a new marketing tool. This would improve MT’s competitive advantage.

Hitachi ABB PG is seeking for cost reductions, shorter cycle time and more sustainable manufacturing methods. More energy efficient production can be used in marketing purposes, but shorter delivery times can also have a great impact on gaining competitive advantage. In case of transformer failures, fast delivery is a crucial factor to win tenders. Hitachi ABB PG is also studying the feasibility of NOVUM material to be used in other technologies and applications. For example, with injection molding they could use the cellulose-based material for producing high volume insulation components and for other applications like boxes and casings.

For CRF the main benefit is the material added in their portfolio. When having green materials in their portfolio they are better prepared for the changing regulation of using plastics in vehicles. Sustainable materials can also be used in marketing and promotion purposes for customers. To answer the emerging demand for green materials they need to have a functional supply chain ready. NOVUM project can help them to tackle this problem.

Table 11. *Benefits obtained from the project by OEM partners.*

Meyer Turku	Hitachi ABB Power Grids	Centro Ricerche Fiat
• Ability and readiness to offer novel product concepts to customers • Stand out from competitors and gaining competitive advantage. • A new marketing tool.	• Cost reductions, shorter cycle time and sustainable manufacturing. • Competitive advantage from shorter delivery time. • Possibility to use NOVUM material in other applications with injection molding.	• Sustainable material. • More sustainable vehicles. • Preparedness and solutions to face changing regulation. • Functional value chain to answer demand. • Marketing and promotion tool.

The main benefit from the project to Brinter is the new product or 3D printer to be added in their product portfolio. After the development phase they can commercialize the new 3D printer in NOVUM project ecosystem as well as for global markets. The printer will be an industrial scale 3D printer which size and operating principle are rather rare in the market. The size will be in the mid-range of commercially available industrial 3D printers, it uses FGF technology and is capable for multi-material printing. Also, NOVUM project can help Brinter to sell solutions rather than technology when the material and methods are added in their offering. With the pilot line Brinter can test and validate this concept in industrial scale which will be a focal marketing asset. Brinter's goal is to gain recurring sales from reselling material, service, and printing heads.

For VTT the main benefits are related to the material development. VTT will have the rights for the developed NOVUM material formulation which can be licensed for profit. However, because of the nature of VTT the most important benefit from the project will be its improved capabilities and know-how for developing bio- and cellulose-based material. In an earlier project, cellulose was identified as a potential 3D printing material. In this project the expertise to develop these kinds of materials have significantly improved. In this project, VTT also developed a fibrous foam printing technology which can potentially have a great effect in the future. Intellectual property rights (IPR) actions have already been taken to protect the nozzle head for the fibrous foam printing technology. The technology is still in laboratory level (TRL 4) and thus will not be included in the pilot line. Other partners as well as external customers have already shown interested in this technology and its applications. Especially packaging industry have indicated interest towards foam printing. Their ambition is to replace expanded polystyrene (EPS) or other fossil-based packaging foams with a new renewable material.

Table 12. *Benefits obtained from the project by R&D partners.*

Brinter	VTT
• New product and material commercialization for global markets. • Products can be commercialized within the project consortium. • An industrial scale 3D printer that is rather rare in the market. • Manufacturing concept including technology, material, and methods.	• 3D printable cellulose-based material formulation. • Improved capabilities and know-how for developing bio- and cellulose-based materials suitable for 3D printing. • Revenue through licensing NOVUM material formulation. • New technologies such as 3D printing with foam.

4.5 Exploitation of technology

In this chapter we discuss how each partner is planning to exploit the results of this project. This will create guidelines how the technology and material should be commercialized and what action still need to be taken to fully exploit the results. In table 13 is presented how each OEM partner is planning to exploit the results. These are approaches that could be chosen if the technology and material are feasible for their applications.

All the OEM partners have considered the option of buying the manufacturing as a service. However, the reasoning behind it is very different between partners. Hitachi ABB

PG and CRF have both also considered acquiring the technology and to make the manufacturing in-house.

MT is planning to utilize the technology for fabricating passenger deck outfittings. The fabrication and installation of the outfittings are made by its subcontractors or subsidiaries. For that reason, it is natural that MT will be buying the manufacturing as a service also in the future. Before technology implementation and demanding it from its subcontractors, MT need to know how the technology and material works. An additional application for 3D printing exploitation MT identified mold manufacturing. This is not in the scope of this project but a potential development project for the future.

Hitachi ABB PG has not decided yet how the technology will be exploited. One approach is to acquire the technology and do the manufacturing of the insulation components in-house. The other approach is to buy the manufacturing as a service from a contract manufacturer. The fabrication of insulation components is currently done in-house which would endorse the approach of acquiring the technology. About 50 percent of the fabricated insulation components are sold to direct competitors and external partners. Acquiring the technology would also provide to Hitachi ABB PG the opportunity to sell customized solutions externally, which could accelerate sales.

Hitachi ABB PG have four insulation kit centers where the fabrication of the insulation components is made. These insulation kit centers serve approximately 50 transformer production sites as well as external customers. Because the production of transformers is highly distributed, buying the manufacturing as a service is also seen as a potential approach for them. However, the economic, functional, and environmental benefits sought from the project can remain low if the manufacturing is bought from an external manufacturer. Additional exploitation path for Hitachi ABB PG would be using NOVUM material in high-volume products and other applications such as boxes and casings. This would require implementing of injection molding. However, Hitachi ABB PG stated that this should be studied more. One great benefit is that CRF is already studying injection molding with NOVUM material, thus reducing the effort needed by Hitachi ABB PG to the further study.

CRF’s approach for exploiting the result is very different compared to other OEM partners. There are two parallel approaches how the exploitation is carried out. The first one is to replace high volume components made from fossil fuel-based polymers with green materials. In this approach the fabrication method will remain the same which is injection molding. In general, the scope of products here are all plastic components.

FCA already have a complete value chain for these components and thus the exploitation would be carried out by its current suppliers. Therefore, finding a material supplier that can supply contract manufacturers proper material in quantity and in right quality is crucial for the exploitation. The current component suppliers have also their own material suppliers that could be utilized in the exploitation.

The second approach for exploiting the results has 3D printing included. This approach is based on two parts. The first part is exploitation in spare part manufacturing and management. The second part is component manufacturing with scope of small-sized parts in low volume series such as sport cars or individual vehicles. Most of the components used in vehicles are produced externally and only a few big-size parts such as dashboard, bumpers and fuel tank are made internally. For this reason, buying the manufacturing as a service from contract manufacturer is the most convenient approach here. In this approach there is also more space in the value chain for new players such as material and component suppliers. However, if CRF wants to ensure the technology, it can be acquired, and the parts produced internally.

Table 13. *Exploitation of results by OEM partners.*

Meyer Turku	Hitachi ABB Power Grids	Centro Ricerche Fiat
• Buy the manufacturing as a service from its subsidiaries or subcontracting network. • NOVUM technology is planned to be used for passenger deck outfittings that are complex in shape and cannot be fabricated affordable in conventional technologies. • Additional application is mold manufacturing.	• Acquiring the technology or buying the manufacturing as a service are both considered. • 3D printing is planned to be used in small volume production. Injection molding with NOVUM material could be used in high volume parts and other applications. • Selling customized insulation components externally.	• High volume components: buying the manufacturing as a service. Here the fabrication technology is injection molding. • Low volume components: fabrication technology is 3D printing and manufacturing either in-house or outsourced. • NOVUM material could be used in all plastic parts in FCA’s vehicles.

In table 14 is presented how Brinter and VTT are planning to exploit the results of NOVUM project. Brinter is planning to exploit the results by selling the 3D printer to manufacturers. Brinter is not interested in contract manufacturing and thus the pilot line will be either sold or dismantled depending on its performance. Brinter’s ambition is to sell solution which would include the technology, material, and methods. The objective here is to enable recurring sales though selling printing heads, material, and services. This would mean that Brinter would be working as a sales agent for VTT’s material. The 3D printer will be fully modular, which means it can run various printing heads depending on the customer’s requests. It is still unknown in under which launch form or platform the commercialization will be carried on by Brinter. The new developed 3D printer can be left under Brinter brand or a new established brand which would have its own customer interfaces. Possible directions would also be establishing a new company or a joint venture. Brinter also notes that finding a large material supplier would serve their exploitation goals the best.

VTT's exploitation is carried out by licensing the material formulation to a material compounder. The material compounder will further supply OEM's or contract manufacturers with NOVUM material. VTT sees that NOVUM material can provide additional value to an existing material compounders portfolio. The material compounder needs to have the capabilities to ramp up the production to the level of customers' demand. However, in the early stage, the material compounder can be a small business. To mitigate the risk of supplying shortages, there should be several material suppliers for NOVUM material. The licensing agreement could also include further material development by VTT. The best solution as a product would be that NOVUM material is a basis formulation which can be modified and optimized according to customers' preferences. To learn more about the possible market, applications and demand, a market study on interested companies and their material requirements should be carried out.

Because the fibrous foam printing technology is still in early stages it cannot be commercialized within this project. However, the exploitation of foam printing technology will include market studying, finding external partners, raising extra funding and further process development. Multi-material printer with integrated foam printing capabilities was identified as the most promising developing path. This technology would enable to produce unique and complex sandwich-structured products. Products from the foam material can also be fabricated with conventional technologies such as molding. This will expand the exploitation possibilities and will extend the applications to high-volume products. The material by itself is inexpensive because it mainly consists of cellulose fibers.

Table 14. *Exploitation of result by R&D partners.*

Brinter	VTT
• Best commercialization path would be to sell solutions to customers including technology, material, and methods. • The launch form or commercialization platform of the technology is still unknown. • Large global material compounders/suppliers are the most potential for material exploitation.	• NOVUM material will be licensed to a suitable material compounder. • There should be several material suppliers to mitigate the risk for delivery problems. • The number of applications where the material can be used is high. • Basis for a cellulose-based material which can be modified and optimized with customers' demands.

In figure 16 are illustrated where each partner's exploitation will take place in the value chain. It also clarifies the missing partners in the value chain. The value chain is still lacking material compounders and contract manufacturers. Finding suitable partners for these roles are extremely important for the exploitation to be successful. First of all, there have to be demand from OEM partners or other external customers. This will justify the existence of the whole value chain. Then, the manufacturing of components need to be conducted either internally or via contract manufacturers. Data to support decisions regarding how the manufacturing will be initially carried out need to be collected and evaluated. Furthermore, the manufacturing needs to be supplied with NOVUM material and with the production/fabrication technology. Here the fabrication technology will be supplied by Brinter, but material compounders and suppliers still need to be involved into the value chain. VTT will license the material formulation to the material compounder.

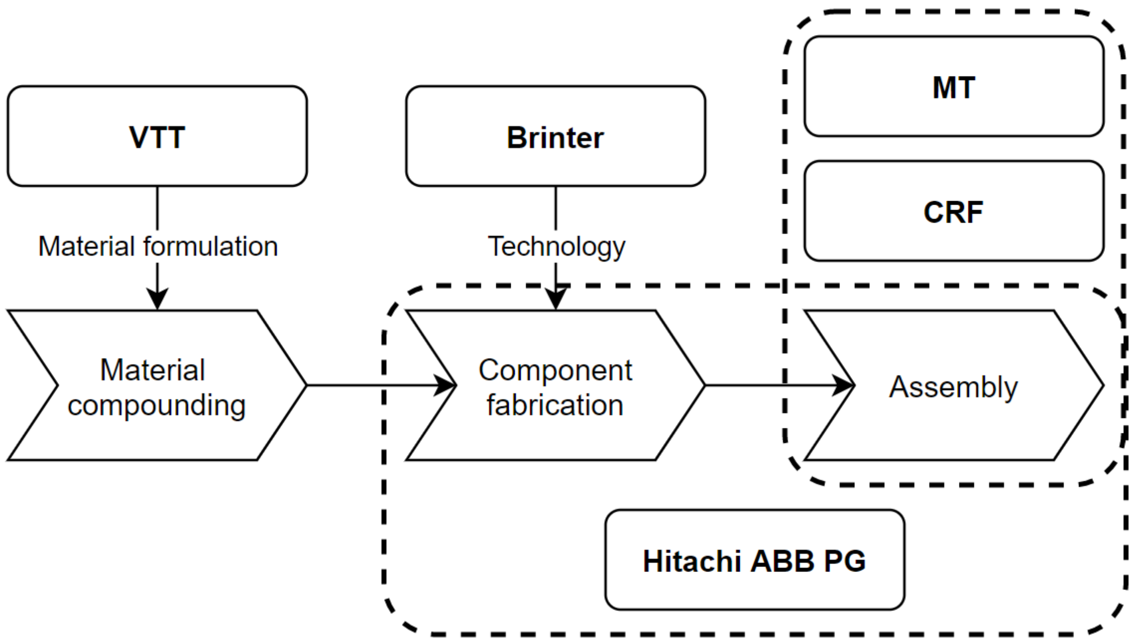

Figure 16. *Exploitation value chain.*

4.6 Potential challenges and barriers of exploitation

In this chapter the challenges and barriers that may occur during the exploitation is presented. It is important to identify the potential challenges beforehand to be prepared and to fix these problems. In table 15 is summarized the challenges and barriers that the OEM partners identified during the interviews. It can be said that MT have many challenges and barriers to overcome before the exploitation of this project can be successful. The first reason for this is that implementing new materials in ship building industry is difficult. It is hard to implement new materials because of the regulation to the material requirements. For example, the material needs to have certain fire resistance properties and weatherproofing.

The other key challenge for MT is its current manufacturing process where the outfitting is done through its subcontracting network. This will create several problems in exploitation. First, if there is lack of interest towards NOVUM technology it can lead to difficulties in finding a right manufacturing partner. Second, the need for a facilitator from MT to push the project forward and a possible absence of one. Last, manufacturing contracts are usually signed before the manufacturing methods are decided. This can lead to conflicts between capabilities of contract manufacturers and the required outcome. Also, the future of the pilot line was mentioned to be a possible barrier because if the pilot line will be dismantled it can be difficult to find a substituting production line.

MT and Hitachi ABB PG are both concerned about the final costs. MT stated that the costs of the investment can be a barrier if the benefits remain low. Hitachi ABB PG is more concerned about the cost of the material. Hitachi ABB PG is currently using cellulose as the raw material for its insulation components. Cellulose in its basic form is inexpensive and thus hard to beat. However, Hitachi ABB PG is trying to reduce the overall costs by other means, thus justifying the use of new more expensive material. It is still unknown where the break-even point will set in the new process. Also, recyclability and final material properties are still unknown and thus identified as potential challenges or barriers. Material recyclability itself is not an issue for Hitachi ABB PG but it can decrease the possibilities for implementing efficient recycling in the production.

CRF’s greatest concern is to find proper material suppliers that can meet their demand and quality requirements. This is because CRF will utilize injection molding as the main fabrication technology and therefore, they need a material supplier that can provide the material in large quantities. Other notable challenge is competitors and substituting materials. There are other players in the market than just NOVUM, offering green materials for injection molding. CRF mentioned that there is a cheaper cellulose-based material for injection molding in the market. Also, legislation could cause challenges what it comes to exporting, importing, safety, chemical compliance, and emissions.

Table 15. *Potential challenges and barriers identified by OEM partners.*

Meyer Turku	Hitachi ABB Power Grids	Centro Ricerche Fiat
• Outfitting is done through subcontracting network. • Lack of interest and finding manufacturing partner. • Need for a facilitator. • Deals with subcontractors are made before manufacturing methods are decided. • Profitability. Benefits are low compared to investment. • Future of the pilot line. • Implementing new materials in ship building industry is hard. • Material properties and fire certification. • Weatherproofing.	• Recyclability of the material. • Material cost. • Material properties.	• Need of material suppliers that can supply proper material in quantity and in right quality. • Competitors and substitutes. • Restriction for exportation and importation. • Safety issues and chemical compliance. • Emissions in production.

In table 16 is presented the challenges and barriers for exploitation that were identified by Brinter and VTT. There were many factors that are common with OEM partners but also differences. In both cases there were concerns about the final material properties and how they will suit the end applications. Brinter added that because some of the end applications are designed to be manufactured with different technologies than 3D printing, it can be difficult to integrate them. Furthermore, the lack of exploiting the capabilities that 3D printing has to offer is a challenge. Product designers must know how to fully exploit 3D printing so the products usability and fabrication can be optimized.

Because manufacturing costs of different products vary much, it is challenging to estimate the break-even point and therefore, the profitability of different batch sizes. Ramping up the production and controlling it can lead to challenges because of the novelty of the pilot line. There have also been challenges in the development process. Brinter mentioned that developing the material and fabrication technology parallel have created challenges. Also, Covid-19 restrictions for travelling have complicated testing and communicating.

From VTT’s perspective the biggest challenge in any technology commercialization is the nature of the organization. This is because the main tasks are research and development activities and for the commercialization VTT needs either external partners or an internal team or a champion that would pursue the commercialization. In the product development phase, there are a few challenges to overcome before the initial exploitation. For further and broader material testing there is need for larger scale material production which cannot be contributed by VTT. Furthermore, extra finance is needed for further research. It is still uncertain how the material development will continue when the funding for NOVUM project ends. Other possible challenges regarding the material are that it is not biodegradable, material properties are not sufficient and the final formulation. If there is a non-commercially available raw material needed in the material formulation, large scale production can be difficult to arrange. Also, there can be challenges regarding the legislation such as fireproofing in cruiser building industry.

VTT mentioned that when companies search for new materials the sustainability can create the initial interest towards the material, but it does not create enough value for the company to implement it. The material properties and the price are seen more important. Hence, if NOVUM material will be commercially successful it needs to deliver other values than just environmental. Furthermore, because NOVUM material is probably more expensive than conventional materials (at least initially), it needs to deliver something that other materials cannot perform. The last challenge identified by VTT is to get material suppliers and end users to involve and to commit to the project at the same time. In this case it means that also the contract manufacturers need to be found if the manufacturing is bought as a service.

Table 16. *Potential challenges and barriers identified by R&D partners.*

Brinter	VTT
• End application suitability and material restrictions. • Finding material suppliers and contract manufacturers. • Lack of exploiting of the technical capabilities. • The manufacturing costs of different products vary much. • Large scale process control including material and process parameter adjustment. • It would be easier to develop the technology to an existing material and vice versa. • Covid-19 restrictions for travelling.	• VTT as a research institution is not an ideal organization for commercializing products. • Producing large volumes of NOVUM material in the product development phase. • Extra finance for further research. • NOVUM material is not biodegradable. • Material properties are not sufficient. • Final material formulation. • Legislation. • When comparing materials, the material properties and the price is more important than if it is bio-based. • The price of NOVUM material and the pilot line. • To get the material suppliers and end users involved and committed at the same time.

4.7 Drivers for exploitation

In this chapter the drivers for exploitation that were identified during the interviews are presented. There was not any distinct question asked about the drivers during the interviews. However, the semi-structured interview created discussion and the topic was brought out on partners own initiative. The drivers are presented in table 17.

One great advantage in exploitation of 3D printing is that there are no other novel competing technologies. For example, in Hitachi ABB PG case the only competing technology is the labor-intensive conventional manufacturing method. It is easy to justify implementation of new technologies if the benefits are significantly higher than in the conventional technology and there are no other choices for gaining these benefits. Also, the 3D printer can be integrated in any existing production line and special equipment's are not required, thus reducing the amount of investment needed.

Cellulose content in NOVUM material is high compared to the ones on the market. This will help NOVUM material to stand out from competitors. CRF mentioned that in the exploitation of 3D printing, one great benefit is the low volume. When the demand for material or components is low, there is no need for big suppliers that would have much of bargaining power. Also, CRF noted that there are no technical barriers for exploitation, and exploitation could be rapid if CRF's current material compounders are used as material suppliers.

Legislation can be a great driver for exploitation. For example, European Commission is currently reviewing its directive on end-of-life vehicles (ELV). The directive was originally adopted in 2000. The aim of the directive is to set clear targets for reuse, recycling, and recovery of vehicles. 85 percent of the total weight of the vehicle's materials need to be reused and recycled and 95 percent of the total weight of the vehicle's materials need to be reused and recovered. Every year 12 million tons of waste is generated by ELV, but this number will increase with accelerating shift to electric cars. The directive on ELV is reviewed because European Commission want to increase recycling, extend the scope to trucks and motorcycles, and set up mandatory requirements for the use of recycled materials and especially recycled plastics in new car manufacturing. Some of the measures might increase the costs of car manufacturers who are less engaged in circular economy. (European commission, 2020) If the initiative on directive on ELV will set requirements for the use of bio-based or recycled materials in new vehicles, it can facilitate the adoption of the technology.

The latter part of the drivers is concerning the unique characteristics of the technology. FGF technology have many advantages over fused filament fabrication (FFF) technology. These advantages were also discussed in the theoretical background of this study. However, few novel points where identified during the interviews. For example, injection molding is not the only conventional technology that can be used to fabricate products with NOVUM material. The market for the NOVUM printer is also identified as less contested than in other segments.

Brinter have identified multi-material 3D printing as an emerging technology. Multi-material 3D printing enables printing of different types of materials simultaneously. NOVUM material can be used in parallel with conventional materials as well as with fibrous foam. This will lower the barrier for exploitation because with the same machine one can produce a wide range of different products. Another unique factor is that the production process is fully automated. There is no need for manual moving of semi-finished products between 3D printing and post-processing stations. Moreover, the processing stations are also fully automated.

Table 17. *Drivers for exploitation.*

- No other competing technologies than the conventional one's.
- 3D printer can be integrated in any production line.
- Cellulose content is significantly higher than in other commercially available materials.
- No need for involving big suppliers.
- No technical barriers.
- Fast exploitation using existing suppliers.
- Plastic ban regulation.
- Granulate-based raw material can also be used in other fabrication methods than 3D printing.
- Granulate form is better for fragile materials than filament form.
- Less competition in granulate-based printers than in filament-based.
- Less competition in the size category of NOVUM printer.
- Multi-material printing.
- Fully automated 3D printing process and pre-processing.

5. ANALYSIS AND DISCUSSION

In this chapter the results of the interviews are analyzed and discussed. Proposals regarding the exploitation and commercialization are conducted. In the first subchapter, first, a proposal for exploitable results are introduced, and then commercially exploitable results are discussed in more detail. In the second subchapter, a proposal for customer value proposition for each OEM partner is conducted. In the third subchapter, the measures for ensuring an effective exploitation of the results are introduced. In the last subchapter, tasks, obstacles, and strategies for commercialization and for capturing the mainstream market are introduced. This analysis is conducted using the theoretical framework that was introduced in the chapter 3.2 Data analysis (see also figure 13).

The exploitation and commercialization are two different subjects, because R&D results can be exploited in other means than just commercial. Innovations can be fully exploited by partners without launching them to the markets. Also, if the innovation is utilized in commercial way but only in one’s own value chain, exploitation is the correct term to be used in this study. However, the economic benefits (sales) can remain low if the R&D results are exploited only in the value chain of NOVUM project, especially for the R&D partners.

5.1 Exploitable R&D results

When this study was planned, only one exploitable R&D result was discussed, the manufacturing concept. However, during the interviews many more potential results emerged. Based on the interview results in chapter 4, four commercially exploitable results and three societally exploitable results of NOVUM project were identified. By dividing the sought benefits into four layers (project, value chain, manufacturing concept, and technology) and further dividing the technology level into three distinct values (economic, functional, and environmental), a wide understanding of the motives and benefits of each partner was achieved. This information was used for creating exploitable results that are most suitable for NOVUM partners in the scope of this study. The exploitable results were divided into commercial and societal one’s based on how they can be exploited.

Commercially exploitable results (CER) and their main stakeholders are presented in figure 17. The CERs are NOVUM material, manufacturing concept, multi-material 3D printing and fibrous foam printing technology. Also, based on the interviews the most important CER for each partner is highlighted in the figure. The stakeholders here are either developers or users. The developers are improving their knowledge of the technology and gaining revenue from future sales. The users will obtain the benefits they were seeking by adopting and implementing these CER’s in their value chain.

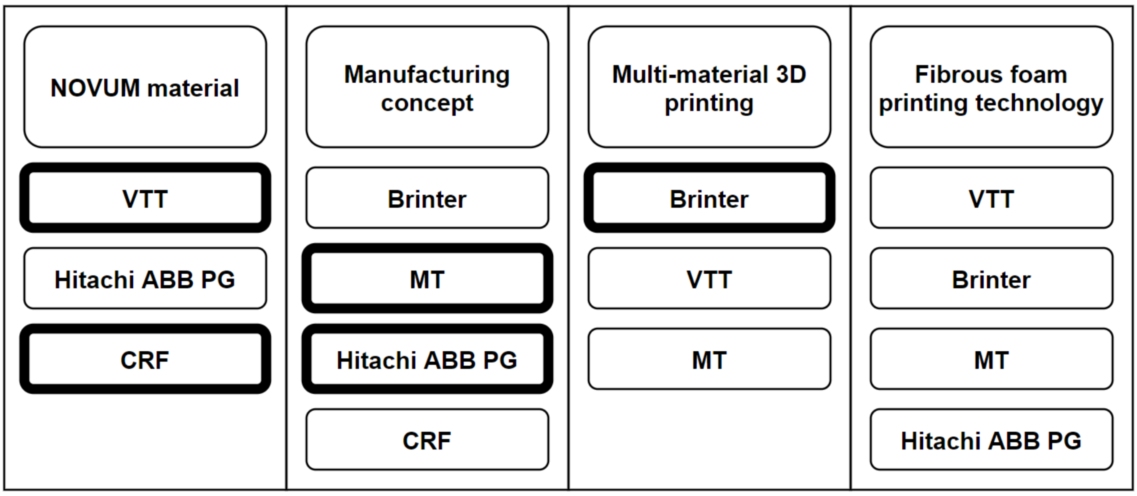

Figure 17. *Commercially exploitable results and their main stakeholders.*

Other exploitable results are the societal ones. These are mainly the results that originate from the benefits sought from value chain level. These results are not that concrete than the commercial ones but can have a considerable impact on the partners performance. The societally exploitable results are:

- networking, information exchange and developed relationships,
- improved know-how and knowledge about the technology and material, and
- future development projects and cooperation.

All partners of the consortium will benefit from these results and therefore, every partner can be defined as the main beneficiary. In the subchapters below, each CER is discussed more in detail and how the beneficiaries are planning to implement them in their value chains.

5.1.1 NOVUM material

The first CER is the novel cellulose-based material (see figure 18). This CER refers to the other fabrication technologies where NOVUM material can be utilized, primary injection molding. VTT is the developer and will be the main beneficiary from commercializing it. The material will be protected by a patent that is still pending and then be licensed to a material compounder. Hitachi ABB PG and especially CRF are also planning to exploit the material with other fabrication technologies than 3D printing. Therefore, they are also been defined as main beneficiaries for commercially available NOVUM material. Both OEM's are planning to exploit the material in high-volume products and with injection molding. Hitachi ABB PG is planning to use the material for producing, for example, boxes and casings. CRF is studying the feasibility of the material with one engine compartment part and two interior components but in general the material could be used for replacing any plastic part in their vehicles. The values for the OEM's are mainly environmental but also economical if the CER is used for marketing purposes, thus for accelerating sales. For CRF, the value can be significant if the review on EU's directive on end-of-life vehicles will set requirements for using bio-based or recycled materials in new vehicles.

Figure 18. *NOVUM material granules (picture acquired from VTT).*

5.1.2 Manufacturing concept

Second identified CER is the manufacturing concept. Manufacturing concept consists of the 3D printer, cellulose-based material, and the automated post-processing line. Here, the manufacturing concept also refers to the pilot line, which is designed and built in this project (see figure 19). Brinter has developed the 3D printer which is utilized in the manufacturing concept and therefore will profit from a successful commercialization.

At the moment, the commercialization launch form of Brinter is still undecided, but it needs to be decided before the end of this project. Either way Brinter will economically benefit from the commercialization. In this CER, Brinter will be the technology provider for a contract manufacturer who will perform the initial manufacturing of components.

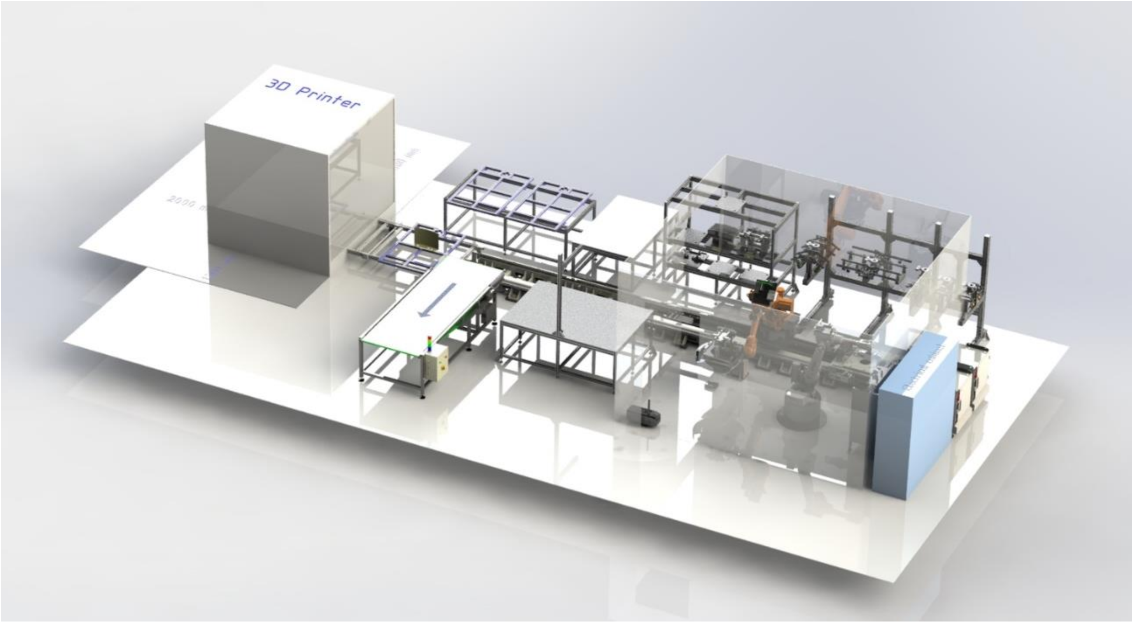

Figure 19. *3D layout design of the pilot line (picture acquired from Abis).*

MT, Hitachi ABB PG and CRF are the indirect beneficiaries from this technology. Although they may not be the manufacturers, they will obtain the benefits regarding the components features and properties that the new manufacturing concept enables. It can be difficult or impossible to obtain all the benefits that were identified in chapter 4.1 Benefits from technology and material - OEM partners if the manufacturing is outsourced. If Hitachi ABB PG decides to acquire the technology themselves, the benefits sought in chapter 4.1 can be more likely achieved. MT and CRF have outsourced the manufacturing of the components that are in the scope of this project. Therefore, it is most obvious that the manufacturing is bought outside also in the future. If Hitachi ABB PG ends up purchasing the fabrication from a contract manufacturer, they need to outsource a part of their current production.

VTT could also be one of the stakeholders in this CER but there are a few reasons why they are not. First, Brinter is one of the main developers and designers of the pilot line and VTT is not. Second, VTT is not one of the owners of the pilot line and therefore is not responsible of commercializing it. Last, VTT will profit indirectly if the manufacturing concept is commercially successful and it uses NOVUM material but VTT have no control over the commercialization process.

MT is planning to utilize the manufacturing concept for producing decorative elements and facades such as bars and pillars for its passenger decks. Additional applications are equipment covers, complexly shaped room dividers, and mold manufacturing. The elements are installed during the outfitting phase. These new products and unique manufacturing capabilities are tools how MT try to get competitive advantage over its direct competitors. One potential and unique exploitation alternative is a mobile production line. Because NOVUM technology is primary used in outfitting phase the demand for the components is highly fluctuated. Therefore, a mobile production line such as a production line built inside a container could be transferred to the site on demand, thus reducing the transportation costs of the elements. This concept of a mobile production line could be easily transferred between different sites and customers.

In MT's case, all the components and products are produced individually but Hitachi ABB PG and CRF are exploiting the technology in small batch production. Hitachi ABB PG is planning to produce insulation components that are small in size. The average size of insulation components is between 15 to 30 cm. The products itself will not create any additional value to Hitachi ABB PG because the products will have at least the same features and properties as products fabricated with the conventional technology. However, 3D printing technology can help them to design more efficient products, thus creating additional value. The main value originates from the evolved manufacturing process and eliminating the use of molds in their process. Eliminating molds in their process will have economic and functional value by making designing, manufacturing, and storing of molds obsolete. CRF is planning to produce personalized parts for premium cars and components for low volume series and sport cars. 3D printing is already used in these applications. Another application is spare part production. The additional value here is received from the capability to fabricate the components with more sustainable material because 3D printing is already used worldwide in spare part production.

The pilot line has a great opportunity to prove and validate that the manufacturing concept is feasible. It is rather rare to validate a feasibility of a technology in a pilot of this scale. The pilot line itself and its performance can be used for marketing purposes. What happens to the pilot line after this project is still unknown. If the pilot line is proven to be functional and feasible, Brinter will try to sell it to a manufacturer. Another partner who will profit from selling the pilot line is Abis who is the designer and owner of the post-processing line. The post-processing line is illustrated more in detail in figure 20.

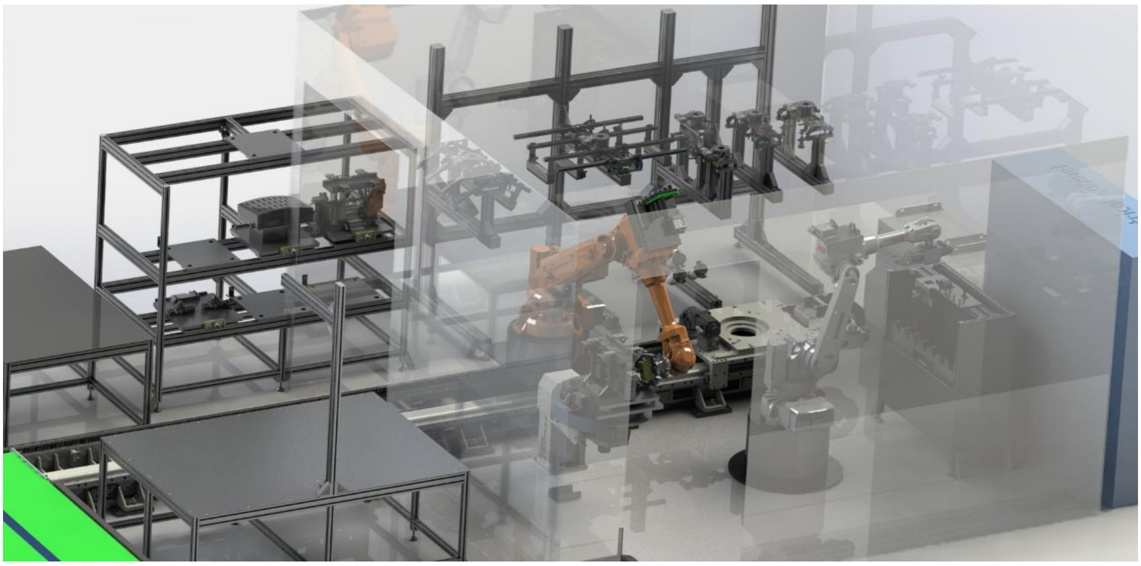

Figure 20. *Fully automated post-processing line (picture acquired from Abis).*

5.1.3 Multi-material 3D printing

Third identified CER is multi-material 3D printing. It is a technology that Brinter have also developed before this project. The novelty in this technology is the new printing head that can use NOVUM material in granular form. In figure 21 is illustrated a test print with NOVUM material. Also, an additional printing head is the fibrous foam printing nozzle. Therefore, Brinter and VTT are both profiting from the commercialization of this technology. Integrating NOVUM material and foam printing heads into a multi-material printer can skyrocket the number of applications where this technology can be exploited. This fabrication method would make possible to produce sandwich-structured composites where NOVUM material would be used in the exterior surface and fibrous foam would serve the role of support material in the core. Sandwich-structured composites are lightweight but have high bending stiffness.

Figure 21. *3D printed lampshade made of NOVUM material (picture acquired from VTT).*

The application area where cellulose-based material and 3D printing can be utilized is wide. As in the literature review demonstrated, 3D printing is most suitable for individual or small batch production and personalized products. Also, complex structures are more convenient to produce with 3D printing. Cellulose as a sustainable biomaterial would be most suitable for environmentally conscious users. These characteristics integrated would indicate that the technology is most suitable for the high-end and premium market.

The commercial exploitation of fibrous foam printing is more likely to occur in this CER because the requirements for foam printing quality and accuracy is rather low when it is used as a filler. MT indicated a great interest towards this kind of solutions and therefore are defined as the main beneficiary as the user in this CER. Their vision is to reduce the overall weight of the vessel or reallocate weight by replacing structures and components with this type of composites. The value for MT is impossible to determine because the concept would be a disruptive innovation. However, the material needs to be fireproof before it can be used in large-scale and for interior outfitting.

5.1.4 Fibrous foam printing technology

Fibrous foam printing technology is the last identified CER. Unlike the previous CERs where the technologies are ready to be commercialized, the exploitation of fibrous foam printing will consist of further research and development. The technology is still in the laboratory phase (TRL 4) and needs to evolve to be technically feasible for commercialization. VTT has made an invention disclosure on the printing nozzle and patentability of the invention is under evaluation. The potential for fibrous foam printing technology is enormous and VTT have already had many contacts from external stakeholders. The opportunity to replace EPS or other fossil-based packaging foams with cellulose-based fibrous foam can have positive influence on environment. For example, low volume products can be packed and supported using fibrous foam printing.

In this technology the benefits are for the most part the same as in NOVUM 3D printing: molds are obsolete. Fibrous foam can also be molded and thus it can be used for high volume products. Brinter, MT and Hitachi ABB PG are the main beneficiaries as the users. Brinter can exploit fibrous foam printing head as an add-on product in its multi-material printer. MT can produce structures and Hitachi ABB PG can produce insulation components that are lightweight, soundproofing, have great heat insulation properties, and vibration damping features. The value for MT of this type of products was already covered in the previous chapter. For Hitachi ABB PG the value and the benefits are the same as in their initial application that were covered in chapter 5.2.1 NOVUM material. However, adopting and implementing this CER would broaden the portfolio for which insulation component production 3D printing can be used.

5.2 Customer value proposition

In new technology commercialization process and business model, customer value proposition (CVP) is one of the main elements to be designed. In this chapter, a proposal for the CVP for each OEM partner is introduced. The CVPs are designed based on how each OEM partner is planning to exploit the results or in other words based on the most important CER (see figure 14). Because the demand for NOVUM technology and materials originated from market pull, the CVP designing starts from identifying high-value customer jobs. First, we compare the novel technology and material to the next-best alternative. Then, a proposal for CVP for each OEM partner is conducted. Anderson et el. (2006) states that a CVP should concentrate on one or two points of difference that deliver the greatest value to the target customer. This approach is called resonating focus. Points of difference are the factors and features that make the offering either superior or inferior compared to the next-best alternative. The CVP might also include a point of parity when it is an essential factor to the customer's buying decision. Points of parity are the factors and features that are shared with the next-best alternative. (Anderson et al., 2006) Therefore, in this analysis, one point of parity and two points of differences were identified, and these are presented in table 18.

For MT the competing technologies are the conventional one's that they are using at present, such as molding and handworks. They also stated that other 3D printing technologies are competing one's but in this analysis the focus is on the conventional. The point of parity is the capability to produce challenging and demanding shapes. Because MT and its subcontractors uses much of manual labor and handworks, they have capabilities to produce rather complex shapes, although with 3D printing the complexness of the shapes will increase. The points of difference are that the fabrication process as well as the installation process is remarkably faster, reduction in material and machining costs and a new more sustainable material. Also, the waste generation will decrease.

Hitachi ABB PG stated that they do not see any competing technologies and thus the next-best alternative is their current production methods. Therefore, the point of parity is the same main raw material which is cellulose. There are many points of difference between these productions, but the main benefits are production cost reductions and shorter cycle time.

CRF stated that the main competing technology is injection molding and materials such as polypropylene (PP) and acrylonitrile butadiene styrene (ABS). CRF also stated that there are other cellulose-based materials in the market, but this analysis will concentrate in their current production and the materials that NOVUM would replace. In CRF's case, they were more interested in replacing their fossil-based materials than the new 3D printing technology. Therefore, this analysis concentrates only on injection molding applications. The point of parity is that with NOVUM material one can fabricate products with the same injection molding machinery. This is important for the commercialization because any additional investments in production are not necessarily required. The points of difference are bio-based and recyclable material and its unique aesthetic look.

Table 18. *Comparison between NOVUM technology and the next-best alternative.*

	MT	**Hitachi ABB PG**	**CRF**
Next-best alternative	Various currently used manufacturing technologies and methods.	Current labor-intensive conventional method.	Injection molding and other plastics.
Point of parity	Complex shapes.	The main raw material is cellulose.	With injection molding NOVUM material can be fabricated with same machinery.
Points of difference	• Faster production and reduced material and machining costs. • Sustainable material.	• Production cost reductions. • Shorter cycle time.	• Bio-based and recyclable material. • Unique aesthetic look.

With help of the comparison in table 18 above, CVP proposals was conducted. These are presented in figure 22. They follow fairly close the point of parity and the points of difference identified in analysis above.

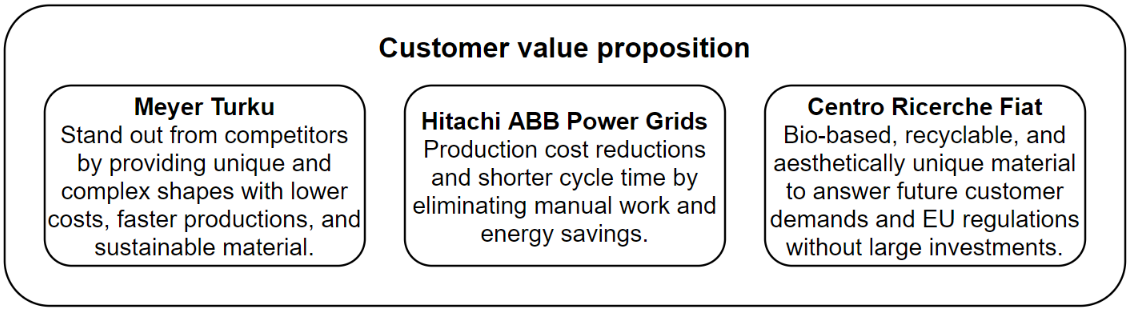

Figure 22. *Proposal for customer value propositions.*

5.3 Exploitation measures

In this chapter, we discuss the concrete measures to ensure an effective and a successful exploitation. Exploitation refers to the actual use of the results by each partner after the project funding ends. A successful exploitation is important for creating credibility of the innovation. Customer references from large brands such as the OEM partners in this project are essential for further commercialization. The exploitation measures are very much interconnected with the elements of business model in commercialization process. The CVP is the foundation that will guide how the rest of the business model elements are designed (profit formula, key resources, and key processes). The exploitation measures should ensure these elements. How each partner is planning to exploit the results of this project is presented in chapter 4.5 Exploitation of technology, and further discussed in previous chapters 5.2.1–5.2.4. The measures that are discussed in this chapter are for ensuring these exploitation objectives. Also, the data from chapters 4.6 Potential challenges and barriers of exploitation and 4.7 Drivers for exploitation were utilized for creating this analysis. The key challenges identified in the interviews were mainly related to ensuring key resources and processes (proper material properties, subcontractors, and material suppliers). The results of the analysis are presented in figure 23.

The measures are not linked in any individual CER, but in general each partner is promoting the CER, which is most important for them (see figure 17). Together these measures should facilitate the adoption of all the CERs. When these measures should be implemented are not discussed because there is much uncertainty regarding the schedule and the maturity of each CER. However, for effective exploitation partners should try to achieve as much as possible during the project funding phase.

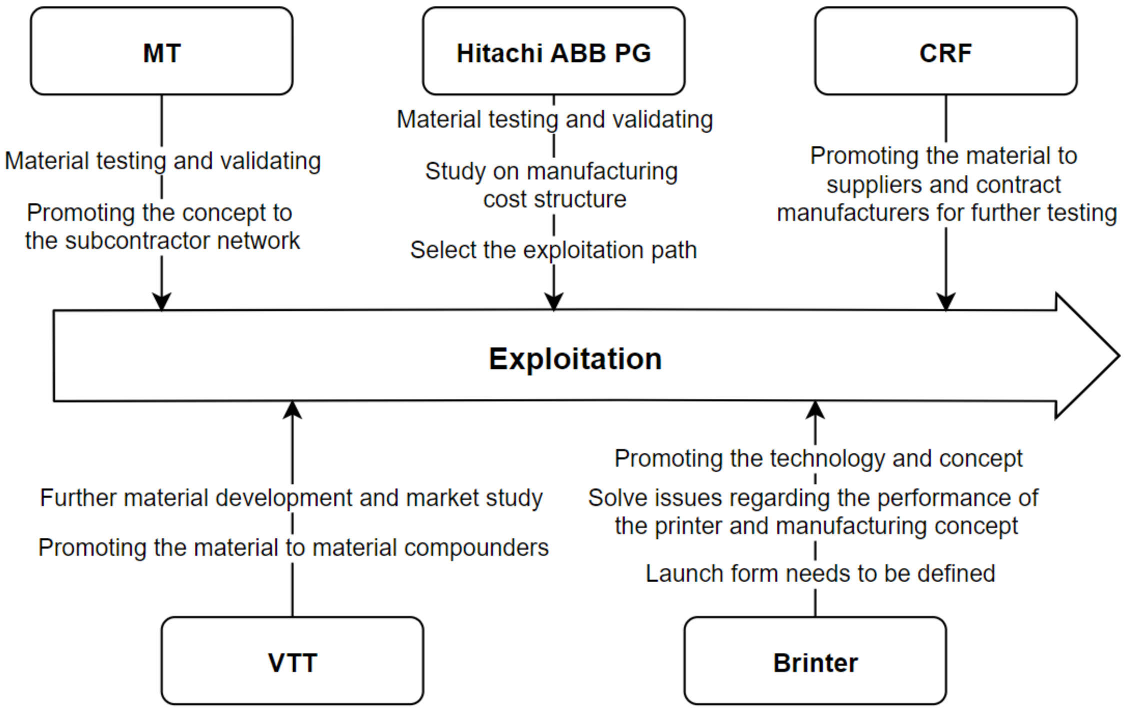

Figure 23. *Measures to counter the challenges and barriers of exploitation and to ensure the exploitation.*

For MT there are many challenges and barriers regarding the material properties. Initially the material is planned to be utilized in outfittings on the sundeck of the cruise vessel. Therefore, and because cruise vessels mainly operate in tropical climate, the material needs to be suitable for harsh conditions such as rain, ultraviolet radiation, and heat. Furthermore, they need to ensure that the material meet their requirements through extensive material testing and validating. Because MT is planning to exploit the technology by buying the manufacturing as a service, they need to promote the manufacturing concept to its subcontractor network. This task is important to be conducted by every partner. By promoting the innovation to their current networks, partners attempt to overcome adoption barriers and facilitate the adoption. Education, instruction, awareness building, and encouraging customers to switch from the old technology are measures for promoting the innovation.

Hitachi ABB PG's application also requires unique and demanding material properties such as oil and electricity resistance. The initial material testing has been promising but further testing and validating is needed for ensuring the technology and material. Hitachi ABB PG have not chosen the exploitation path yet. They will either acquire the technology and make the production in-house or outsource the production and buy the manufacturing as a service. Therefore, they need to study which alternative is more cost-effective. Furthermore, they need to evaluate other factors regarding make-or-buy decision and other non-economic benefits obtained from each alternative. In this study, many benefits were identified for mainly in-house production.

CRF's ambition is to exploit the NOVUM material within its current value chain. Therefore, CRF needs to discuss and promote the material to its material suppliers and contract manufacturers to find out their capabilities for producing the material and for fabricating the components. In this task, VTT also have a key role in communicating, sharing knowledge, and providing material to the value chain. CRF is fairly confident what it comes to the technical performance of the material. Therefore, further material testing is not highlighted here, although it is most certainly happening. For CRF exploring new materials and technologies is also more or less risk management because they are preparing for changing legislation.

VTT's main objective is to successfully launch the novel cellulose-based material to the markets. One obstacle before the market uptake is to find a material compounder. For this, VTT suggested that the initial compounder could be a smaller business at first. They need an external material compounder to meet the growing demand for a broader material testing. VTT is not capable and it is not its primary task to provide materials in this scale. Therefore, to fulfill the growing demand for NOVUM material, VTT should initially find a small-scale compounder. After the material is validated by different customers or end users, a large-scale compounder or compounders are needed. Multiple material compounders and suppliers will mitigate the risk for supplying shortages and the competition will keep the price reasonable. Furthermore, because the demand of the user side in this project (MT, Hitachi ABB PG and CRF) is rather unsteady and low, VTT needs to conduct an extensive market study of potential customers, applications, and target markets. Also, the material requirements of these target customers need to be studied, because VTT's ambition is to develop a modular and flexible material that can be configured based on the customer requirements. To mitigate the risks in the development process, new end users and customers need to participate to the funding. One big question is how necessary material's biodegradability is for potential customers. At the moment the material is not biodegradable in short-term.

During the interview, Brinter could not tell which is the launch form of the technology. The options here are that the technology is launched by themself, a spinout, a subsidiary, or a joint venture. Brinter needs do discuss with potential partners about joint ventures or other type of cooperation such as strategic alliances. According their website, Brinter as a brand including mission and vision, leans strongly towards bioprinting and so the target group is entirely different in this project. 3D bioprinting is used for printing tissues, organs, or drugs in industries like pharmaceutical, biotechnological, and cosmetic. Hence, Brinter would probably not be the best brand for commercializing NOVUM technology. A new brand is suggested to be established. There are much of uncertainty regarding the performance of the 3D printer and the manufacturing concept. For example, the full capacity of the 3D printer and the post-processing line, cycle time of each product, need for manual labor and service, material feed, operating costs, and bottle necks. The pilot line is co-owned with Abis, who is the designer and the owner of the post-processing line. It is in their both interest if the pilot line is sold after the project. Therefore, they should take co-operations for promoting the manufacturing concept and pilot line. Furthermore, Brinter should promote the multi-material 3D printer for potential customers or manufacturers.

The test drives of the pilot line are also critical for the exploitation of the manufacturing concept. Because the pilot line is fully automated it needs to be adjusted and controlling large scale process can create challenges. If the perform is insufficient it can be a great drawback for the exploitation of R&D results. Therefore, there should be a clear plan how to proceed if this happens. Fortunately, the other CERs are still feasible if the pilot line fails or it is not suitable for end applications.

The material price was mentioned as a potential barrier by all the partners. However, the cost of the production equipment was only mentioned by MT. This is probably because CRF is more interested in the material than the technology and Hitachi ABB PG have higher volume and steadier production which enables dividing the investment costs for higher number of units. The final cost structure estimate and life-cycle cost analysis are conducted by Arditec Association at the end of NOVUM project. The material price is estimated to initially be higher than other similar materials. At the moment VTT estimates that the material cost in laboratory environment is 200 €/kg but they further state that the cost could decrease to approximately 20 €/kg in large-scale production. The average material cost for most generic PLA and ABS filaments is approximately 25 $/kg (Goldschmidt, 2020). These are not the main competing materials, but it gives some perspective on the price. It is also difficult to compare NOVUM material to other cellulose-based materials. Typical cellulose-based 3D printing materials are composites, where cellulose and its derivatives are compounded with conventional 3D printing materials such as PLA and ABS. In these applications, cellulose is used in lower content (under 30 percent). (Wang et al., 2018)

5.4 Commercialization of project's results

In this chapter, commercialization process including tasks, challenges and strategies are discussed. These are related to the key resources and processes to be ensured before the launch of innovations. In this study commercialization refers to the use of the results beyond the project partners or in other words launch of new product to the target market. The greatest challenge in this R&D project is that the initial objective was to develop a more efficient manufacturing process not product. The manufacturing concept and the pilot line represents the more efficient manufacturing process. The problem is that none of the project's partners are willing to acquire the technology and start manufacturing in-house (at the moment Hitachi ABB PG is considering to acquire the technology or buy the manufacturing as a service, but have no interest towards the pilot line). Therefore, the exploitation of the manufacturing concept requires an external contract manufacturer to acquire the technology. Another problem is how to commit the contract manufacturer to purchase the manufacturing concept because the benefits identified in this project are unique for the OEM partners and generated in the perspective that the partners will do the manufacturing in-house. It would be easier to request the contract manufacturer to acquire the technology if the innovation would also include the product. Or in other words, if the product cannot or is not feasible to manufacture with other technologies. With current information the manufacturing concept will not make conventional technologies obsolete. However, if the pilot line will prove to be a superior against other manufacturing methods, it will facilitate the adoption of this concept. In conclusion, this problem relates only to the manufacturing concept not the other CERs. For conducting an effective exploitation of the manufacturing concept, finding a contract manufacturer is the main issue.

The architecture of the CER's are also very different. Where NOVUM material and multi-material 3D printing technology are autonomous or stand-alone innovations, the manufacturing concept is a systemic innovation. Hence, adopting the manufacturing concept requires a significant readjustment of the whole system and therefore many actors in the adoption network need to be persuaded to support the innovation.

It is most convenient to discuss about the commercialization tasks and challenges through the manufacturing concept because it contains also the NOVUM material and the multi-material 3D printing technology. Fibrous foam printing is discussed here only briefly because of its low TRL grade. There are three focal tasks to be conducted before the manufacturing concept can be fully exploited by each partner, and especially before launching the technology to the mainstream market. These are: finding a material compounder and supplier, finding a contract manufacturer, and finance of the production line, as presented in figure 24. For launching NOVUM material, only key process and resource to secure is the material compounder and supplier. By conducting these tasks, the value chain can be ensured, which is a key resource and process in new technology product commercialization. The commercialization process becomes complicated when all these tasks need to be conducted at the same time. The launch of the multi-material 3D printing technology requires no additional key resources or processes because it is business as usual for Brinter.

The TRL for the pilot line will be 6 at the end of the project, which means that the pilot line or the manufacturing concept needs to be implemented in actual operational environment to get to the highest TRL 9. Hence, when the manufacturing concept is exploited by any partner the technology will get the highest TRL grade. After this, the manufacturing concept can be properly commercialized. For positively affecting the post-purchase attitudes of early adopters, at launch, the configuration needs to be ready and the critical functionalities are included and working perfectly.

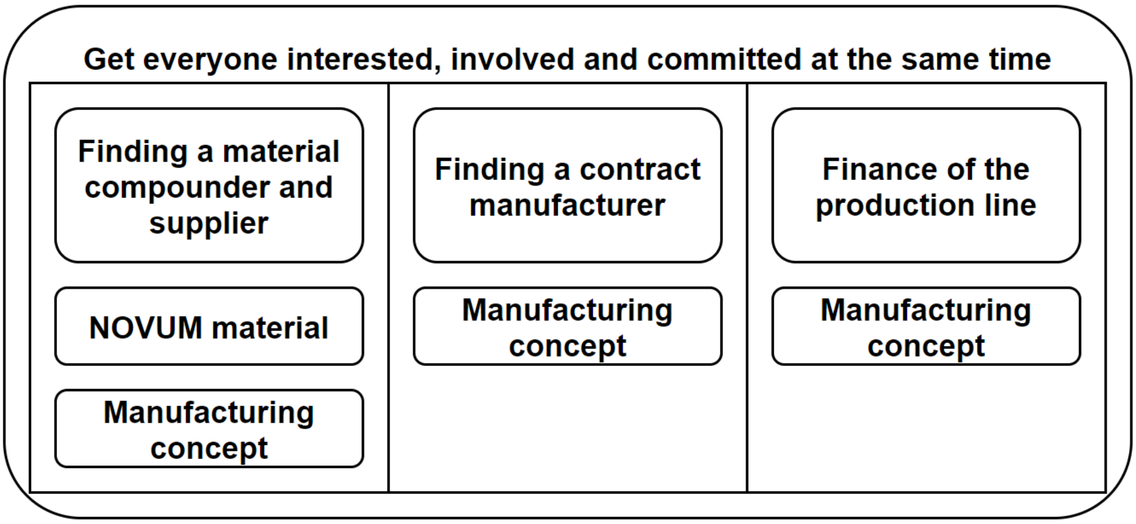

Figure 24. *Key resources and processes to secure before the launch of NOVUM material and manufacturing concept.*

5.4.1 Finding a material compounder and supplier

Finding a material compounder and supplier is especially important for two CERs: NOVUM material and manufacturing concept. It is obvious that material supply is important for these. NOVUM material cannot be sold if there are nothing to sell and manufacturing concept will not run if there are no raw material. However, multi-material 3D printing can utilize various raw materials because of its modularity and fibrous foam printing technology uses entirely different raw material. VTT has the main responsibility for finding a material compounder. Because VTT has done material development for decades it has a wide network of potential material compounders. However, utilizing the OEM’s current material compounders and suppliers could facilitate the exploitation because the value chain is already existing. Utilizing an incumbent material compounder and supplier is seen as the most attractive commercialization strategy by every partner. However, the size of the material compounder has divided the partners. Some states that a large material compounder and supplier would serve their operations best when others are supporting a small business. A large business would have the resources to produce the material in high quantity and promote the material through its distribution channels. However, in the launch phase the quantities are still rather low, and a small business would have a lower bargaining power of supplier.

5.4.2 Finding a contract manufacturer

Finding a contract manufacturer is most important for the exploitation of the manufacturing concept. Only Hitachi ABB PG is still considering acquiring the technology. This task needs to be conducted with close cooperation between Brinter, Abis and the OEM partners. It is proposed that, first, the contract manufacturer is sought from partners existing value chains, and then, broaden the scope. The pilot line has been designed to be suitable for all the OEM partners. So, if the pilot line would eventually be sold to one contract manufacturer, which would supply components to all the OEM partners, many of the benefits sought in this project would not fulfill. This is because of the long distance between each partner. Ideally 3D printing should be exploited in distributed manufacturing. Hence, finding additional customers close to OEM partners and establishing three separate production lines is the most suitable solution. Other commercialization strategy would be a strategic alliance where Hitachi ABB PG acquires the technology and then agree to supply MT and CRF. For MT this arrangement would be suitable because of the uneven demand and the relatively short distance from Poland to its shipyards in Finland and Germany. However, in CRF case this might not be the best solution because of the higher demand and lead time requirements of spare parts. Also, it is not studied yet, if one production line has the capacity to serve all the OEM partners.

5.4.3 Financing of the production line

The financing of the production line is also a critical task for exploitation. At the moment, the 3D printer alone is a significant cost for a contract manufacturer. According to Brinter, the hardware of the 3D printer, which is designed and built for the pilot line, have a cost of approximately 50 000 € excluding the printing heads, which are 10 000-

30 000 € each. Therefore, it can be said that in its most basic configuration, the cost of a 3D printer is over 100 000 €. When more printing heads are added and the post-processing line is included, the cost will increase even more. This means that a small- or even a medium-size business probably does not have the assets to invest alone in this technology.

One solution would be that the OEMs will participate by partly funding the production line and thus be co-owners of the production line. For mitigating the economic risks of acquiring the technology, OEM partners could also establish a joint venture. The joint venture would have a base clientele from its owners and when the demand is secured and steady, they could start to expand their operation to new customers and segments. Because this is not OEM's core business, the joint venture could be sold to a larger contract manufacturer after a successful launch. Other convenient commercialization strategy would be gathering funding for the production line from venture capitalist or other sources of funding. In this approach the manufacturing should be controlled by one or several NOVUM partners, and therefore a subsidiary or joint venture needs to be established. The problem with these approaches is that initially the partners were not interested in in-house manufacturing. Also, who would be the facilitator in these approaches is unclear. The potential material compounder does not need any additional investment into equipment as long as the production volumes are rather low.

Because Hitachi ABB PG was the initial and only end user when the planning of manufacturing concept began, the configuration is mainly designed on their terms. Although the manufacturing concept is designed to be suitable for all the products that were in the scope of this project, it may not be the most optimal and cost-effective configuration. Therefore, it can be discussed how necessary the post-processing line is for MT's configuration. Their sought benefits are more related to the bio-based material, design complexity, and faster production; not cost reductions. Hence, MT would obtain the desired benefits with a less expensive configuration of the manufacturing concept. Also, the uneven demand and large size of the components can drive for a stripped-down version. MT stated also that they were planning to exploit the technology inside the existing value chain, meaning that their current contract manufacturers or subsidiaries would conduct the manufacturing.

In conclusion, it is extremely difficult propose which mode is the best for exploitation of the manufacturing concept before the final cost structure estimate and life-cycle cost analysis are ready and the pilot line's capabilities are known. When this information is available, OEM partners should analyze and compare the differences between in-house and outsourced manufacturing. Not only in monetary term but to consider all the benefits that are obtained if the technology is adopted. The potential approaches identified in this analysis are:

- Strategic alliance where one production line is owned and operated by Hitachi ABB PG,
- three separate production lines locating close to each OEM partner (requires additional customers),
- one production line operated by one external and large contract manufacturer,
- one co-owned production line operated by one external but smaller contract manufacturer,
- one production line owned and operated by a joint venture,
- one production line owned by venture capitalists and operated by a subsidiary or joint venture, and
- three separate and customized production lines owned and operated by an external contract manufacturer or in-house.

6. CONCLUSIONS

This chapter concludes the thesis. First, a summary of the results of this study is presented and reflected to the literature. Second, practical implications are introduced. Third, limitations of the study are described. Last, proposals for future research are presented.

6.1 Summary

The objective of this study was to investigate the factors that affect the commercialization of innovations and how the R&D results are effectively exploited. To answer these questions, the customer value was studied by interviewing potential end users of the case R&D project. The case selected in this study was NOVUM project. A multi-national publicly funded R&D project with aim of developing a new efficient and sustainable manufacturing process. The challenge in implementing the R&D results in partners' value chains is much greater in publicly funded and multi-national R&D project consortium. All the main partners are operating in different industries and therefore their products vary much what it comes to size, structure, shape, and desired material properties. Moreover, the identified customer values are different for each end user, and therefore a consistent commercialization strategy can be difficult to design.

Realizing potential customer value of new technology has been identified to be one of the success factors for commercializing innovations. However, the topic is stated to be under-researched. Kirchberger and Pohl (2016) further stated that the benefits of studying and understanding customer value in early phase could be a powerful argument for commercializing new technology. (Kirchberger & Pohl, 2016) This study tries to validate this argument to be true. Realizing potential customer value early in the commercialization process can help to recognize the full potential of the innovation and potential challenges in the commercialization process.

An interesting finding from the literature review was that identifying potential customer value is not included in Datta et al. (2013) commercialization process of innovations (Datta et al., 2013). Analyzing customer valuer could have a great contribution in the deployment stage before manufacturing strategy and launch strategy are developed. In this study, customer value has been the foundation and placed the boundaries for making the make-or-buy decisions and creating the launch strategy.

Identifying general as well as project related challenges was one of the subobjectives in this study. As presented in the literature review and in a study made by Aarikka-Stenroos and Lehtimäki (2014) there are multiple challenges in commercializing radical innovations. Realizing potential customer value can help to overcome many of these challenges. First, it can lower the level of uncertainty which is affecting the decision making. Second, it can help to understand the customer's perspective. Third, it can help to create credibility towards the innovation by indicating the real customer value. Fourth, understanding what truly delivers value to the customer can facilitate the adoption. Last, exposing potential customers to the innovation early can help to create first sales.

This study gives many proposals how the commercialization of NOVUM project should be conducted. It tells what the main challenges are and propose countermeasures to ensure an effective exploitation. The same process can be conducted in any technological innovation's commercialization. The challenges and therefore the exploitation measures focus mainly on ensuring the key resources and processes. These capabilities are needed for creating and delivering the customer value proposition to the end customer. As demonstrated in the literature review, key resources and processes are one of the main elements of a business model (Johnson et al., 2008). Hence, it can be said that utilizing business models in commercialization process can be a useful tool.

For commercializing innovations, the main tasks were to first, understand the real customer value by interviewing potential customers or end users. Then to design individual customer value propositions for each potential customer, and after that, secure the key processes and resources that are required for creating and delivering the customer value. The launch will focus on the innovators, who are the forerunners and technological enthusiasts of the market. These users represent around 3 percent of the market. The commercialization is considered to be successful if innovation is gaining ground from the mainstream market, early adopters. The customer value propositions designed in this study are clearly most suitable for the innovators market. The customer value identified in this study can be utilized in evaluating and choosing new markets and narrowing down potential customers.

The greatest challenge identified in this study is that when the development activities are related to manufacturing process, not product, the exploitation can be extremely difficult when the initial manufacturing is outsourced. When the innovation is systemic not autonomous or stand-alone, the exploitation and adoption require more stakeholders. This will create extra work and requires seamless cooperation between partners.

Especially, like in this case, the external stakeholders (material compounder and contract manufacturer) need to get interested, involved, and committed at the same time. Hence, the greatest challenge in commercializing technological innovations is the incomplete value chain. Also, fully automated production line can be difficult to configurate and optimize when there are many end users as customers. The greatest drivers in other hand are superior performance and the low competition in new markets.

In this study, a theoretical framework for commercializing R&D results was developed and utilized for analyzing the results. The framework demonstrated the process from gathering data from end users to commercialization analysis. The benefits of adopting the R&D results of NOVUM project are indisputable. When benefits of the innovations and the value that these benefits deliver to each potential customer are known, individual customer value propositions can be designed. However, as in the literature review demonstrated, the incentive to purchase can be defined as the difference of customer value and costs. Therefore, the adoption of a technology is more complicated than only demonstrating the benefits and the customer value. However, the cost estimates were not in the scope of this study.

In figure 25 is illustrated the summary of this study. It can be generalized so it can be used for commercializing any 3D printing technology with a sustainable material. The figure follows the same structure as the theoretical framework. The commercially exploitable R&D results identified in the study are, first, cellulose-based material that can be utilized with different fabrication methods such as 3D printing and injection molding based on the production volume and the need for complex structures. Second, manufacturing concept that merge all the innovations developed in R&D project into one production line. Third, multi-material 3D printing that can use multiple materials in one fabrication run producing sandwich-structured composites. Last, fibrous foam printing technology that can be exploited in small batch production of lightweight and porous components. The main economic, functional, and environmental benefits of these innovations are presented in the figure. How each end user prefers these benefits were analyzed and based on that customer value was identified.

The customer values were simplified and concretized by designing individual customer value propositions for each industry as shown in the figure below. Analyzing customer value seems to be suitable for business (marine and electrical insulation industry) and consumer markets (automotive industry). Customer value brought out the differences between the industries such as what are the preferences of each industry and how should the exploitable R&D results be exploited in their favor. The customer value was the main driver in commercialization planning. Challenges and barriers also create restrictions and obstacles to be solved in the commercialization process. For the launch to have the possibility to be successful, key resources and processes need to be ensured for creating and delivering the customer value that was defined earlier. In the analysis the focus is on the key resources and processes that the ecosystem does not have.

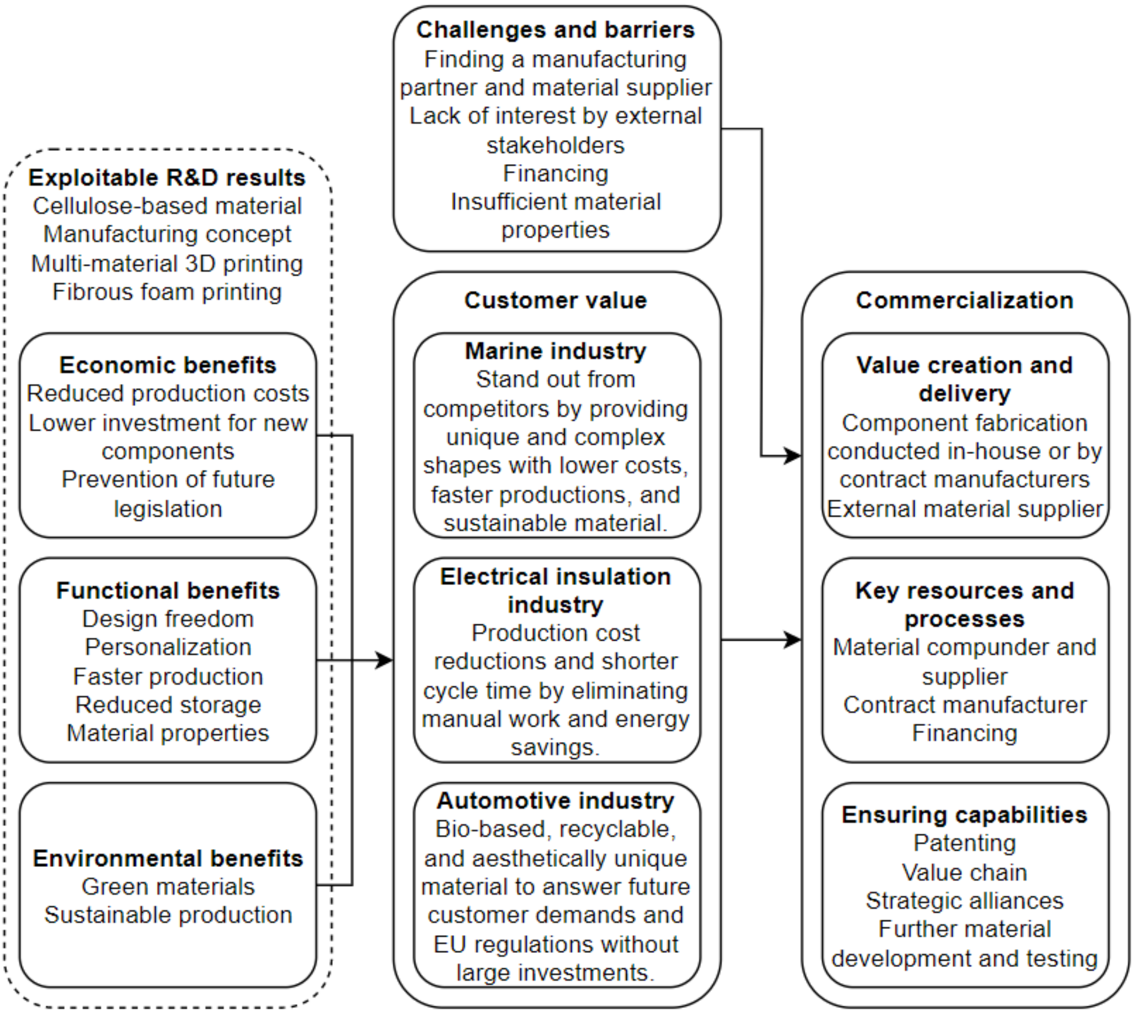

Figure 25. *Summary of results.*

One interesting finding in this study was that when the end users were asked about the benefits of adopting the technologies, they all answered as they would be the initial manufacturers, although later they told that the technology will be exploited externally. This is confusing when creating the analysis because these benefits do not exist anymore in that event. This finding implicates that analyzing customer value of process innovations is more complicated because of the distributed and outsourced productions.

6.2 Practical implications

The results of this study can be utilized in commercialization of innovations. As a result of this study three recommendations to managers who are working with innovation commercialization are made.

1. Managers should discuss with potential end users about the sought benefits to obtain knowledge of the real customer value.

The most suitable areas would be radical innovations or products which market does not exist. Radical innovations can include values or applications that only end users can recognize. Therefore, managers should discuss with potential end users about the sought benefits and exploitation to obtain knowledge of every application area and their value to the end user. This will create multiple exploitation paths and help managers to identify which is the most attractive. When managers know what truly delivers value to the customer, they can enhance the adoption and overcome adoption barriers by arguing the facts to the customers.

For example, in this study the initial exploitable R&D result was the manufacturing concept but after the interviews, three commercially exploitable R&D result arise. When customer value is fully understood, the market segmentation is easier to conduct. As Anderson et al. (2006) stated, the improvements of the technology should concern the points of difference which deliver the greatest value to the target customer (Anderson et al., 2006). Therefore, if the real customer value is recognized early in the R&D project, it can reduce the development cost of unimportant features and improve the customer perceived value of the most important features.

The core perceived benefits of innovation are the main input in defining customer value. Customer value is the basis for evaluating commercialization potential and creating commercialization strategy. This study shows that end user involvement in early phase at commercialization process can help managers to identify the real customer value. In early phase, value chain can be designed to create and deliver the desired customer value. It also shows that one value chain cannot satisfy all the potential customers and multiple launch strategies can complicate the commercialization process. Hence, analyzing customer value can help to identify different commercialization strategies. For example, in this study the sought benefits by the end users differ and the benefits are interconnected into individual R&D results. Therefore, one commercialization strategy cannot satisfy all the partners. The theoretical framework developed in this study helps managers to identify critical factors affecting the launch by analyzing customer value.

2. Managers should analyze customer value before making make-or-buy decisions in process innovations.

One major finding in this study was that the end users described the benefits of adopting the technology as they would be the initial manufacturer. However, most was planning to exploit the technology through a contract manufacturer and therefore this will hinder the benefits of adoption. Customer value is a great tool in evaluating the benefits of in-house and outsourced production because managers can easily compare which values are delivered in each alternative.

3. Managers should use customer value for identifying key resources and processes that are needed for a successful launch.

To create and deliver desired customer value, key resources and processes need to be identified and ensured first. Chiesa and Frattini (2011) argued that one major way for influencing customer acceptance is affecting the attitudes of early adopters. These attitudes can be positively affected by ensuring that the configuration is ready, and all the critical functionalities are included at the launch. (Chiesa & Frattini, 2011) Customer value can contribute here by helping managers to identify key resources and processes as well as key features for a successful launch.

One significant limitation identified in this study was the absence of the initial component manufacturer and material supplier in the R&D project’s value chain. This creates much of uncertainty for the launch of innovations as demonstrated. Managers should emphasize the need for complete value chain in open innovation development projects. In this case study the component manufacturer will conduct the initial investment in the new technology. Therefore, the absence of the stakeholder that have to invest the most into the hardware can lead to failure of exploitation.

Sustainability is an emerging factor in industrial operations. Although the case project has a sustainability goal, it is not the driving factor as demonstrated in the results. The direct or indirect goal is always gaining economic benefits from adopting the innovation. Sustainability is a tool for companies to gain competitive advantage over its competitors which lead to economic benefits.

6.3 Limitations of the study

The greatest limitation in this study is the uniqueness of the case project. Five stakeholders of the case project were interviewed. Three of the stakeholders were representing the customer side and although they represented different field of industry the results may not be transferable as they are. The results to be easily transferable into another innovation’s commercialization project, the innovation and value chain chosen should be similar kind than in NOVUM project.

The credibility of this study is estimated high. The research method was interviewing project partners of the case project. They have all invested in the R&D project and a successful exploitation will benefit their all. Therefore, the data collected in the interviews is reliable. Also, the persons interviewed were the persons in charge in the project and thus have the best knowledge about the innovations and the exploitation paths. However, there is one great limitation that was identified after the interviews was conducted. The role of the end users changed during the interview. First, the end users described the potential benefits gained from adopting the new technology as the initial manufacturer. But, when asked how they are planning to exploit the new technology, buying the manufacturing as a service was the most common answer. This means that the sought benefits may not occur in the different role in the value chain.

High credibility leads to good level of dependability. However, in the case project NOVUM, the situations have altered through the whole project and the objective of the R&D project have also changed. Therefore, the results in this study reflects the findings of one certain period in the R&D project. This can hinder the dependability or repeatability of this study.

6.4 Proposals for future research

Classifying customer value into three segments economic value, functional value, and environmental value seems to suit well for busines-to-business market. However, previous research of this has not been made and therefore it should be studied more. The literature cover well customer value in consumer markets but they tend to emphasize symbolic and emotional values when in business market decisions are more objective.

Environmental value was included in the analysis made in this study. A conclusion of this study states that environmental values are not the key drivers for adopting a new technology, but the economic benefits obtained through it. However, this is just one view made from the results and should be studied more. Especially comparing companies’ strategies and the decision drivers could tell if the external communication is aligned with its actions.

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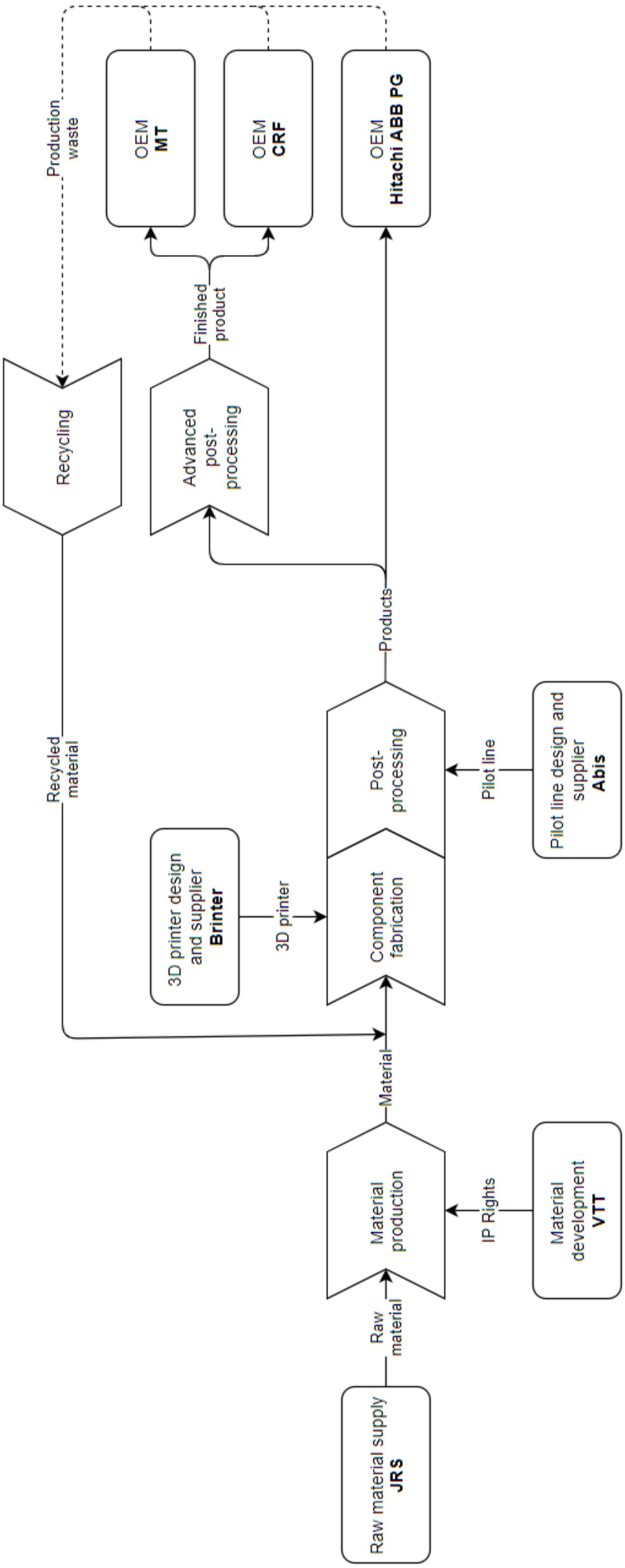
APPENDIX A: NOVUM VALUE CHAIN



APPENDIX B: CUSTOMER VALUE CREATION FRAMEWORK

Customer Value Creation Framework

	Types of Value			
Sources of Value	**Functional/Instrumental Value**	**Experiential/Hedonic Value**	**Symbolic/Expressive Value**	**Cost/Sacrifice Value**
	• Correct/accurate attributes • Appropriate performances • Appropriate outcomes	• Sensory • Emotional • Social/relational • Epistemic	• Self-identity/worth • Personal meaning • Self-expression • Social meaning • Conditional meaning	• Economic • Psychological • Personal investment • Risk
Information	Information informs, educates, and helps customers realize performance and outcomes.	Copy and creativity can provide or enhance sensory, emotional, relational, and epistemic experiences.	Can position a product, help consumers identify with the product, help them make associations, and interpret meaning.	Helps consumers evaluate alternatives; make more informed, faster, and less stressful decisions; helps lower prices by greater competition.
Products	Products directly provide features, functions, and characteristics that allow performances and outcomes.	They provide sensory (e.g., restaurants), emotional (e.g., Six Flags), relational (e.g., board games), and epistemic (e.g., Disney Land) experiences: augmenting goods (e.g., IKEA) or as the focal product (e.g., Club Med).	Products enhance consumer self-concepts (e.g., Mac cosmetics), provide personal meaning (e.g., Campbell's soup), offer self-expression (e.g., Gap clothes), and provide social meaning (e.g., Hallmark cards).	Product price and augmented product considerations, such as operating costs, assembly, ease of use, warranty, and service terms, help to reduce costs and sacrifices.
Interactions (with employees and systems)	Sales call frequency and duration, service interactions and responsiveness, and interactions with systems (such as the telephone, billing, or customer support system) provide or enhance desired performances and outcomes.	Service attributes, such as staff politeness, friendliness, or empathy, create sensory, emotional, relational, and epistemic experiences for customers, as do service recovery, customer support, and other systems.	Staff and system interactions can make customers feel better about themselves and provide personal meaning to customers; privileged interactions support status and prestige. Equity policies can enhance sociocultural meaning.	Interactions with people and systems (such as electronic data interchange) add to or reduce the economic and psychological cost of a product and increase or reduce the personal investment required to acquire and consume the product.
Environment (purchase and consumption)	Furniture, fixtures, lighting, layout, and other decorative features and attributes of the purchasing or consumption environment contribute to functional/instrumental value by enhancing or detracting from product performances and outcomes.	Features and attributes of the purchasing or consumption environment such as music, ambiance, and atmosphere can create sensory, emotional, and epistemic experiences for customers.	Where a product is purchased or consumed can provide personal, social, or sociocultural meaning and can enhance self-worth and expression—a cup of coffee at an outdoor cafe may have more symbolic value than coffee at home.	Contributes to the economic cost of a product (e.g., popcorn at a movie theater), psychological cost (such as finding parking downtown), personal investment (how much searching is required), and risk (personal safety).
Ownership/Possession Transfer	Correct, accurate, and timely fulfillment processes (such as order taking, picking/packing, and delivery) provide functional/instrumental value.	Fulfilling delivery promises and how a product is delivered (such as the presentation of a meal) can enhance the customer experience—as can pride of ownership and product potency (future potential).	How a product is delivered (such as gift wrapped or via a ceremony) and by whom (such as the manager of a car dealership) can create symbolic value.	Can be enhanced with payment terms, delivery options, return policies, billing accuracy, order tracking systems, access to supplier personnel, and dispute resolution procedures.

APPENDIX C: QUESTIONAIRE FOR OEM PARTNERS

1. What are the key reasons you participated in this project and what are your goals?

1.1. What are the benefits you are seeking from NOVUM technologies?
- Economic value (for example, cost reductions in transportation and labor)
- Functional value (for example, customization, design freedom, flexibility)
- Ecological value (for example, waste/energy reduction, recyclable/renewable material)

1.2. What are the benefits you are seeking from the manufacturing concept?
- Manufacturing concept refers to all the developed technologies as one i.e. industrial scale 3D printing with cellulose-based material

1.3. What are the benefits you are seeking from the value chain level in this project?
- For example, relationships, joint action, networking

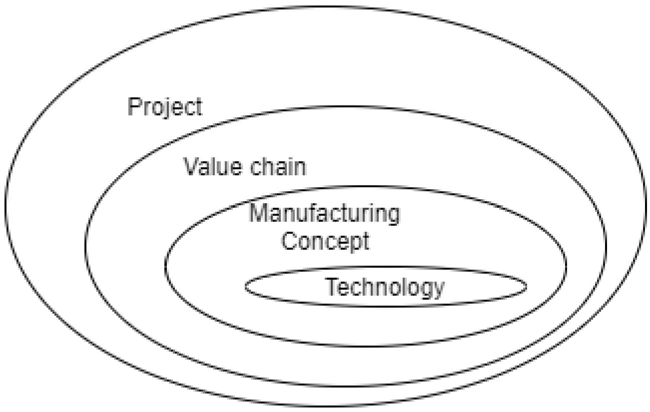


Figure 1. Different layers in NOVUM project.

2. How are you planning to exploit the technology and material created in NOVUM project?

   For example:
   - Acquiring the technology
   - Buy as a service
   - Design and manufacturing service / prototyping service
   - Rent printing time in fab lab

3. Are you seeking to create new business i.e. accelerate sales, gain cost reductions or to develop more sustainable production methods? Or a combination of these? Which one is your main incentive?

4. For which products are you planning to utilize the technology of NOVUM project?

4.1. What is the competing technology or manufacturing concept?

4.2. What are the unique characteristics in NOVUM technology compared to competing technologies?

5. What are the challenges and barriers that may occur in the exploitation of NOVUM technology?

APPENDIX D: QUESTIONAIRE FOR R&D PARTNERS

1. What are the key reasons you participated in this project and what are your goals?

2. What are the benefits that the NOVUM technology is offering to the customers?
   - Economic value (for example, cost reductions in material and labor)
   - Functional value (for example, fabrication speed, flexibility)
   - Ecological value (for example, waste/energy reduction, use of recyclable/renewable material)

3. What are the benefits you are seeking from the value chain level in this project?
   - For example, networking, joint action, cost sharing, knowledge sharing

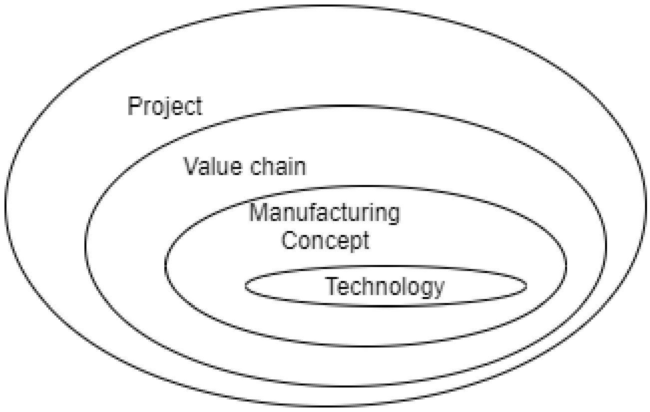


Figure 2. Different layers in NOVUM project.

4. How are you planning to exploit the technology and material created in NOVUM project?
   1. What is the competing technology or manufacturing concept?
   2. What are the unique characteristics in NOVUM technology compared to competing technologies?
   3. What are the key factors to obtain (sustainable) competitive advantage?
   4. How are the developed technologies protected?

5. In what other applications and industries, the technology and/or material can be used?
   1. Short and long-term vision?
   2. How will the technology develop in the future?

6. What are the challenges and barriers that may occur in the exploitation of results?