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Jukka Luhas

Increasing returns by path-dependency: The case forest industry transition in Finland

Examiner: Associate Professor (Agr. & For.) Mirja Mikkilä
Instructor: Postdoctoral researcher (SuSci.) Anna Kuokkanen

TIIVISTELMÄ

Lappeenrannan teknillinen yliopisto
LUT School of Energy Systems
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Jukka Luhas

Polkuriippuvuuden tuotot Suomen metsäteollisuuden muutoksessa

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Suomen metsäteollisuuden jalostusarvo on tippunut 7 miljardista 4 miljardiin euroon vuosien 2000-2016 aikana. Metsäteollisuuden tuotevalikoima 2010-luvulla on perustunut, ja näyttää tulevaisuudessa perustuvan alhaisen jalostusarvon tuotteisiin. Tämä diplomityö on ensikosketus Suomen metsäteollisuuteen systeemimuutoksen (system transition) näkökulmasta. Painopiste keskittyy perinteisiin ja korkean jalostusarvon biotuotteisiin vuodesta 1850 lähtien. Tavoitteena on tunnistaa polkuriippuvuudesta (path-dependency) saatavia tuottoja (increasing returns) ja pohtia innovaatioiden etsinnän lukkiutumista (lock-in) Suomen metsäteollisuuden muutoksessa. Moniulotteisia tuottolähteitä kuten biotuoteinnovaatioita, kuluttajalähtöistä liiketoimintaa, tavoitteita ja sertifikaatteja on hyödynnetty vähän huolimatta tunnistetusta potentiaalista. Perinteisesti metsäteollisuuden innovaatioiden etsintä on ollut polkuriippuvaista. Metsäteollisudeessa on ollut tekno-institutionaalisen kompleksin (techno-institutional complex) piirteitä. Toimia tarvitaan kohti korkeampaa jalostusarvoa, uusia työpaikkoja ja ilmastonmuutoksen torjuntaa.

ABSTRACT

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Increasing returns by path-dependency: The case forest industry transition in Finland

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Keywords: system transition, sustainable development, path-dependency, lock-in, increasing returns, added-value, forest industry

The total added value of Finnish forest industry has decreased from 7 billion to 4 billion euros in between 2000-2016. The product selection of forest industry in the 2010s is based, and will most likely based on low-value products in the future. This thesis is a first touch to Finnish forest industry from system transition point of view. More precisely, the focus here is to the traditional forest industry products and high-value bio-products since 1850. The aim is to identify increasing returns of path-dependency and consider the lock-in of innovation search in the case forest industry transition in Finland. The multidimensional sources of increasing returns such as bio-product innovations, user-driven business, targets and certifications have exploited slightly despite of identified potential. Traditionally, the innovation search of forest industry has been path-dependent. The forest industry have had implications of techno-institutional complex. Actions towards higher added value, jobs creation and climate change mitigation are needed.

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ABBREVIATIONS

CAFWI	Central Association of Finnish Woodworking Industries (1918-1970s, later CAFFI)
CAFFI	Central Association of Finnish Forest Industries (1970s-1992, later FFF)
FFF	Finnish Forest Industries
LCA	Life Cycle Asssesment
LULUCF	Land Use, Land Use-Change and Forestry
MLP	Multi-Level Perspective
UNCED	United Nations Conference on Environment and Development

1 INTRODUCTION

The Finnish government tackles the most serious issue in the world, climate change by bioeconomy that offers many ways to mitigation and at the same time, growth and jobs can be created (Kröger & Raitio 2017) (Global shapers community 2017) (EBCD 2015). Finland has already requirements for successful bioeconomy in general, but in global level, economic, environment and society improvements are needed. (PTT 2017a)

The Finnish forest industry is reforming (Finnish Forest Industries 2017a). The product selection of the forest industry in the 2010s is based, and will most likely based on traditional products that added value is low (Prime Minister’s Office 16/2017) (PTT 2017b). Pulp exports have almost tripled in between 2009-2018 (PTT2017c). Nevertheless, the Finnish government and forest companies have had plans to increase added value in order to avoid for being only raw material producer (Prime Minister’s Office 16/2017) (PTT 2017c).

The results towards higher added value have been low in the last decades, which motivates examine mechanisms that brakes the transition. This thesis is a first touch to Finnish forest industry from system transition point of view. Thesis outlines increasing returns of path-dependency, lock-in and TIC, and considers the lock-in of innovation search in the case forest industry transition in Finland.

1.1 Background

The added value of the forest industry has decreased from 7 billion to 4 billion euros in between 2000-2016 (Luke 2016a). Bulk production in the Finnish forest industry has increased (Prime Minister’s Office 16/2017) (PTT 2017b). In 2018, part of the new investments plans are branded as biorefineries that are generally pulp mills that utilize side streams and life cycle thinking without having significant differences compared to traditional pulp mills (Maaseudun tulevaisuus 2018) (Aino 2016) (Ranne 2015). The forest industry has lost 10 000 employments since the 1990s, and one third of the employments in the forest industry are in danger (Aino 2016) (Helsingin sanomat 2017). The forest industry has been important employer, especially in the counties where high unemployment rates occurs due to impulsive restructuring concerning to forest industry (MMM 2016) (Häyrinen 2011). The research concerning to new products and product development of the forest industry needs more investments (Prime Minister's Office 16/2017). The bioeconomy has potential to double the returns (Hänninen 2013).

The research of Finnish forest industry have long roots in the history, whereas sustainability research has created much later. So far, there have been lack of interdisciplinary research of these two sectors. This thesis approaches Finnish forest industry via new way.

1.2 Research Objectives

This thesis focuses on traditional forest industry products and high-value bio-products since 1850, when industrialization accelerated in the forest sector. The dominant production of forest industry started to change from home industry e.g. tar-burning and slash and burn agriculture to centralized sawmill, pulp industry. (Leppälä 2012, 277, 289) (Kotilainen & Rytteri 2011). The focus of this thesis is presented as the red rings in Figure 1.

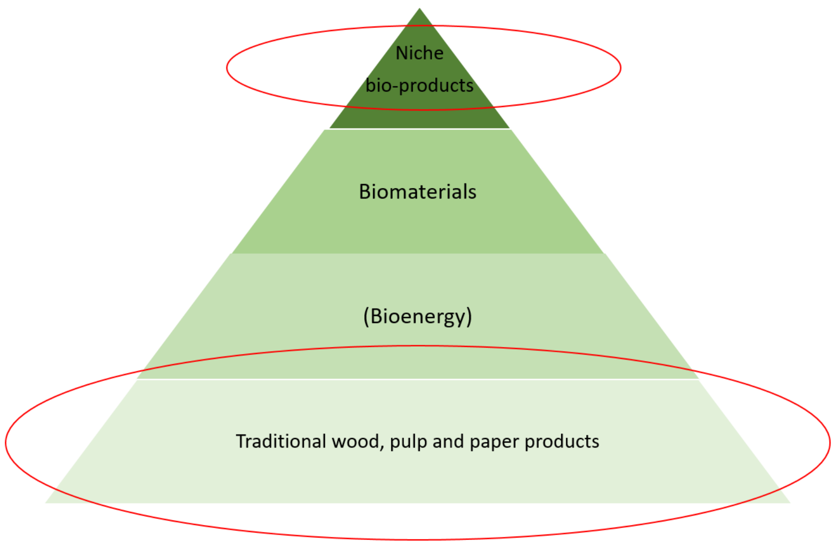

Figure 1: Value pyramid of forest-based bio-economy

Figure 1 contributes how low value traditional wood, pulp and paper products accounts the big part of value pyramid, whereas high value bio-products accounts the minor part. The traditional sectors of forest industry, pulp and wood-product industries have been the most intensive wood consumers in the last century, and its added value of the products has been low in the last decades (Luke 2017a) (VTT 126, 2013). In the future, competitiveness of the forest industry is based on high value products rather than bulk production (Hänninen 2013). New technologies and products are necessary for the success of the forest industry (PTT 2017a) (Hänninen 2013).

Transition is analyzed from production, product portfolio and organization point of view. Efficient production and sustainable raw material have been the key for success of forest industry after the WW2 (Seppälä 2000, 11). Increased product selection due to demand and extended processing have had important role for the economy (Lammi 2000, 13) (Seppälä 2000, 11). Organizations' closely relations have created Finnish forest cluster that interactive dynamics have gained positive externalities by cooperation and competition (Seppälä 2000, 13). Forest cluster has had specific political status that has increased its' competitiveness and power especially in between 1970-2000 (Lammi 2000, 13) (Huuskonen 2009).

System transition has been applied in studies such as transportation (Geels 2005) and aviation sectors (Geels 2006). Path-dependency and lock-in have been applied in studies such as P&P industry (Novotny & Laestadius 2014), transportation (Oberling et all. 2012), energy for road transport (Klitkou et all. 2015), agricultural (Chhetri et all. 2010) and food systems (Kuokkanen et all. 2017). Low added value, almost tripled pulp exports, investment plans related to traditional pulp mills (Prime Minister's Office 16/2017) (PTT 2017b) (PTT2017c) (Maaseudun tulevaisuus 2018) (Aino 2016) (Ranne 2015) alarms on path-dependency and lock-in of the forest industry, which motivates discover increasing returns and complex system in the forest industry transition.

The aim is to identify the increasing returns of path-dependency, lock-in and TIC through production, product portfolio and organizations, and consider the lock-in of innovation search in the case forest industry transition in Finland.

1.3 Material

The material of system transition and path-dependency is based on international scientific articles, whereas the material of forest industry transition is based on diverse domestic material as Table 1 presents.

Table 1: Description of used material.

Themes	Material type	Main authors
System transition	Scientific articles	Geels
Path-dependency	Scientific articles	Arthur, Unruh, Foxon, Könnölä et all
Transition in production	Scientific articles	Kotilainen & Rytteri
	Literature	Leppälä, Paaskoski, Ahvenainen, Lammi
	Research reports	PTT, VTT
	Statistics	Luke, Kunnas
	Articles	Hetemäki, Finnish forest industries, Huuskonen et all
Transition in product portfolio	Literature	Helander, Sierilä, Paaskoski & Virtanen, Hilden et all, Lammi
	Research reports	Prime Minister's Office, VTT, PTT
	Statistics	PTT, Luke
	Articles	Salste, VTT
	Media	Yle, Aino
Transition in organizations	Scientific articles	Kotilainen & Rytteri
	Literature	Helander, Sierilä, Laurila et all, Kuisma et all

Table 1 contributes how the material of forest industry transition is more diverse than the material of system transition and path-dependency. The material of product portfolio transition includes more media sources than other themes.

1.4 Methodology

Qualitative research discovers material on the whole, and simplifies remarks for concluding enigma. (Alasuutari 2011, 39-39). Interpretations do not require empirical verifications by statistics, because it is not needed or possible (Smith 2000) (Alasuutari 2011, 39). Narratives are diverse texts in a storied form (Riessman 2005). Storyline is the most important feature of narratives because it bonds simple occurrences together (Kujala 2007, 27). Narratives' events are selected and examined as significant for a specific audience. Nations, government, social movements, organizations, scientists and professionals write narratives about history. (Riessman 2005) Narrative analysis is valuable e.g. organization transition (Koskinen et all. 2005).

This thesis examines the forest industry transition in general level. Lack of quantitative material and storied form material from diverse organizations forces to use qualitative method, precisely narrative analysis as a method. The forest industry transition and the results are examined chronologically as possible for creating a story form.

2 THEORETICAL FRAMEWORK

Following section contributes theory of sustainable system transition and introduces theory of path-dependency, lock-in and TIC. In the end, operative framework in the forest industry transition is outlined.

2.1 Sustainable System Transition

Sustainability research creates a basis of early preventative warning system that can alert threats and respond them by long-term network and decision-making processes (Sondeijker et all. 2006) (Loorbach 2010). Transitions are important in sustainable development because they can allow radical improvements (Meadowcroft 2005). Figure 2 outlines multi-level perspective (MLP) on system innovations (Geels 2002).

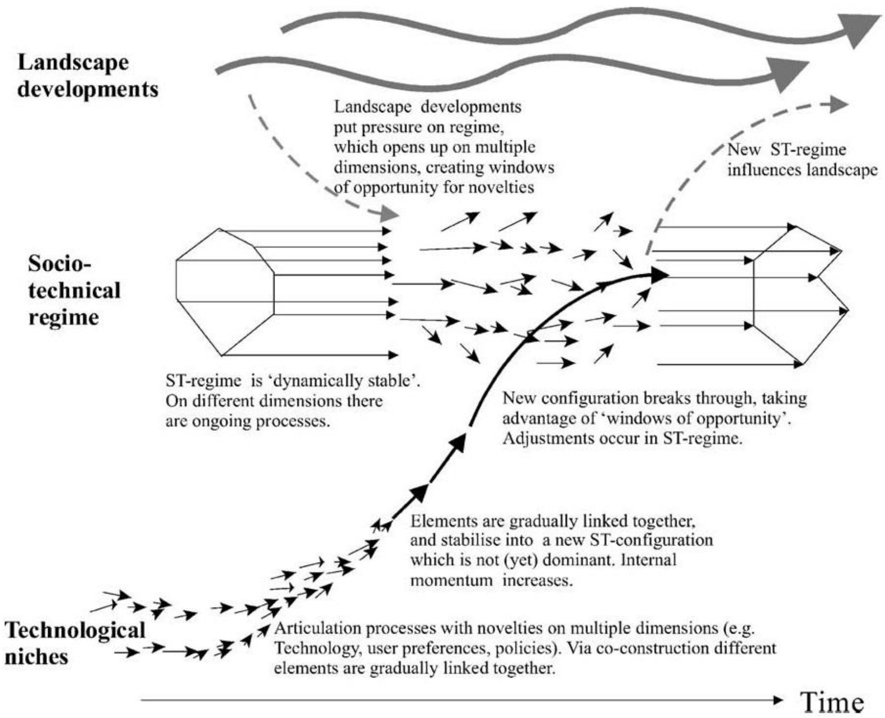

Figure 2: A dynamic multi-level perspective on system innovations (Geels 2002).

Figure 2 contributes how technologies transition is the outcome of development from multiple levels, technological niches, sociotechnical regimes and sociotechnical landscapes (Geels 2002). The connection between the elements stabilizes regime level, but radical innovations can pop up from niche level to processes at the regime (Geels 2002).

2.2 Path-dependency

Pioneers Paul David and Brian Arthur analyzed mechanisms, which can make technologies path-dependent. David (1985) examined connection between historical small events and learning effects to achieving dominant market share. Arthur (1994) examined increasing returns in four classes: scale economies, learning effects, adaptive expectations and networks effects. Scale economies by large production runs can lower unit costs. When set-up costs are high, organizations identify and stay with single option. Learning effects by gained knowledge by using and repetition leads to higher returns. Individuals adapt their actions by projections. Returns by networks effects increases when use attracts still more users. The "chosen" technology do not have to be superior for having increasing returns to adoption and blocking all other technologies from the market, even the competitive technologies have similar functions (Cowan, Gunby 1996).

2.3 Lock-in

Gregory Unruh (2000) found that path-dependency by technological and institutional increasing returns to scale can lead to lock-in of technological and institutional co-evolution. Institutional lock-in appears as an intervention of government policy and making legal frameworks. Industry standards, technological interrelatedness and co-specialized assets are part of industries lock-in. (Unruh 2002) Timothy Foxon (2014) examined how systems previous states affects to present states, which affects to future states in the environment, where technologies are in coevolution with institutions, business strategies, companies and governments. Technological lock-in appears when economic and cultural advantages develop to incumbent technologies for blocking potential adopters or competitors, which occurs as a path-dependency on technological innovation and deployment (Foxon 2014).

2.4 TIC

Unruh (2000, 2002) discovered how advanced techno-institutional lock-ins could appear in TIC, which can brake the development of alternative technologies. In TIC, coevolution in between technologies, organizations, societies and institutions lowers economic, social and psychological cost of a dominant design for advancing functional technological systems (Unruh 2000, 2002). Members of TIC creates rules and takes care of its self-perpetuation, e.g. government ministries and regulatory agencies are active part of which (Könnölä et all. 2006). Development of technology is like a yeast cell growth; branches are developing to different directions and there are cross-connection and inter-actions in between companies and technological regimes (Rip & Kemp 1997).

Techno-institutional lock-ins in TIC can brake the emergence of alternative technological solutions (Unruh 2000). Incumbent firms do not create innovations that could replace current dominant design. Change can destroy the value of firms' technological competence, which lead that firms try to sustain dominant design by improvements and rent seeking. (Unruh 2002) Sanditov (2005) found that innovations have higher value in incumbent technology, which affects a direction of innovation search. Innovators are likely to be well paid especially improving institutional and strategic innovations, if simple transactions are insufficient (Liebowitz, Margolis 1995)

Liebowitz and Margolis (1995) studies contributes how inferior technology continues as a dominant if variable cost of old technology are lower than average total cost of new. Increasing returns to process might lead to single equilibrium that is resistant to change, but still, dominant technologies in rational environment are vulnerable to small events and expectations (Pierson 2000) (Foxon 2014). Relatively small events in path dependent processes can have large consequences in politics, if they occur in right time (Pierson 2000). Innovations by increasing returns can replace incumbent technologies, because experiments shows that none of technologies dominates forever. On the other hand, increasing returns can also push innovations towards market standardization and lock-in (Unruh 2006). In general, entrepreneurial entrants that works outside of the dominant design can create and commercialize new technologies (Unruh 2002). If new technologies can pop out, they can survive due to protection and specialized markets, because they are weak compared to dominant regime (Rip & Kemp 1997).

2.5 Operative Framework

The MLP has been popular used approach for understanding past, current and future transitions. The MLP approach has applied in many historical transition cases such as transportation (Geels 2005) and aviation (Geels 2006). Geels (2005, 2006) uses MLP to make an assessment of drivers and barriers for a transition towards low-carbon transportation, and analyzing evolutionary economic technological change. So far, the MLP has not applied in Finnish forest industry. The MLP approach is applied by creating framework for this thesis as red dotted lines presents in Figure 3. Red arrow presents path-dependent process.

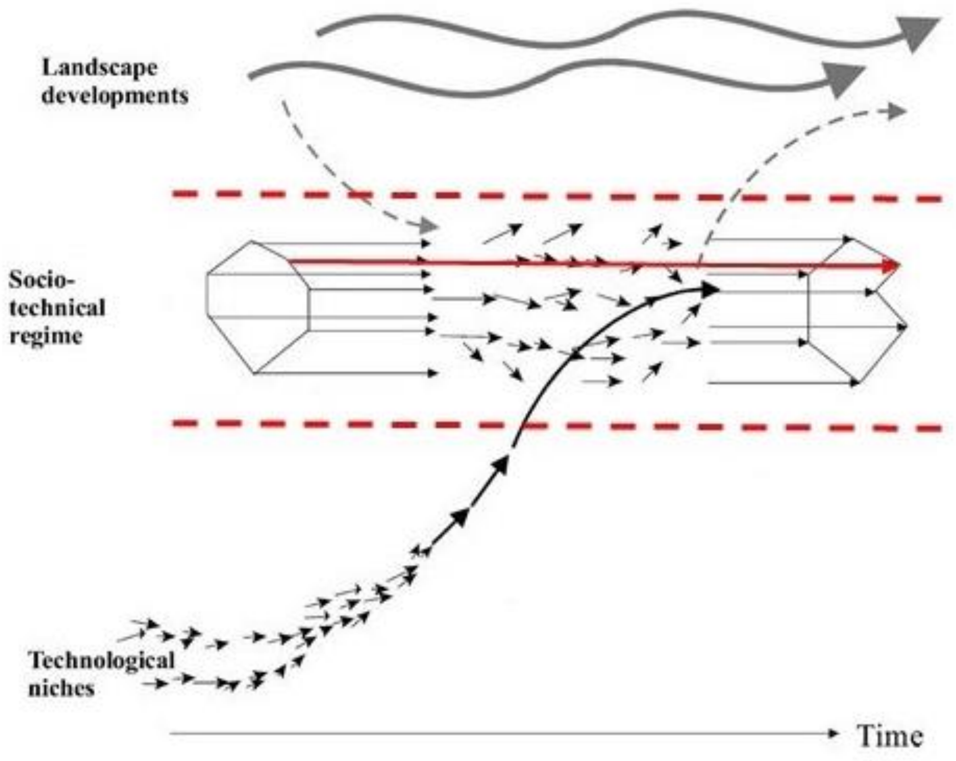

Figure 3: The operational framework of thesis, adjusted by a dynamic MLP on system innovations (Geels 2002).

Figure 3 outlines how thesis is focused on sociotechnical regime, where processes forms by externalities. Landscape developments, in this case, e.g. climate change put pressure on socio-technical regime. Technological niches, in this case, e.g. bio-products tries to break through for changing incumbent regime.

Path-dependency has been discovered by David (1985) and Arthur (1989), which theory has been extended later in transition research such as the case of energy for road transport (Klitkou et all. 2015), food system (Kuokkanen et all. 2017) and hydrogen economy (Könnölä et all. 2006). Klitkou et all. (2015) extended theory of path-dependency for comparative analysis while Kuokkanen et all. (2017) identified dimensions of socio-technical increasing returns. This thesis identifies the increasing returns of path-dependency in the forest industry transition.

Pierson (2000), Unruh (2000, 2002) and Foxon (2002) have discovered technological, institutional and industrial lock-ins. Studies of lock-in have focused on e.g. forest industry (Novothy & Laestadius 2014), food (Laborde et all. 2016) (Kuokkanen et all. 2017), agricultural (Chhetri et all. 2010), transportation (Oberling et all. 2012) and hydrogen energy (Könnölä et all. 2006) systems. Könnölä et all. (2006) considered existing hydrogen energy system as techno-institutional complexes. Laborde et all (2016) made empirical analysis of techno-institutional lock-in, whereas Novothy & Laestadius (2014) identified industrial transformation and lock-in of technology and innovation through product portfolio, R&D and vertigal linkages. This thesis identifies the increasing returns of lock-in and TIC, and considers the lock-in of innovation search in the forest industry transition.

3 FOREST INDUSTRY TRANSITION IN FINLAND

The forest industry has faced challenges over the centuries, which have forced industry towards transition. In the end of the 19th century in Finland, transition happened from tar-burning to sawmill industry. (Hetemäki 2009) In the early 21st century, the whole bio-product sector is in global transition due to changes related to technology, environment and society (PTT 2017a). In addition to Finland, forest industry transition is occurring also in Sweden and Canada (Hetemäki 2009). Weyerhauser has changed paper and carton production to mechanical forest industry, forestry and biofuel development. International paper has sold graphic paper production and concentrates packaging carton. In Finland, all the companies have almost similar business portfolio as 10 years ago, despite of Metsä Group that has changed graphic paper to carton, tissue paper, pulp and construction products. (Tekniikka & talous 2014)

"The forest industry in Finland is currently facing economic transition which traditionally strong remits give way" - Hetemäki 2009

The beginning of current transition has been difficult in the all sectors. It is important to notice that the transition is not necessarily affect to the whole forest sector, e.g. transition has been different between paper and carton industry. (Hetemäki 2009) For the better understanding of current transition, it important to examine the history of forest industry and the previous transition.

3.1 Transition in production

In Finland, production of goods used to be home industry until 19th century (Leppälä 2012, 277). Local inhabitants utilized forest freely by slash-and-burn, tar burning and small-scale use (Kotilainen & Rytteri 2011). The wood itself had no price, and the price determined by workloads, until the improvements in the forest industries increased the value of the wood (Paaskoski & Virtanen 1995, 36). The international economic boom accelerated industrial production and exploitation of timber resources in the 1870s (Kotilainen & Rytteri 2011).

Figure 3 outlines the wood consumption of Finnish forest industries in between 1860-2016 and rare estimations of Kunnas (2007) tar calculations.

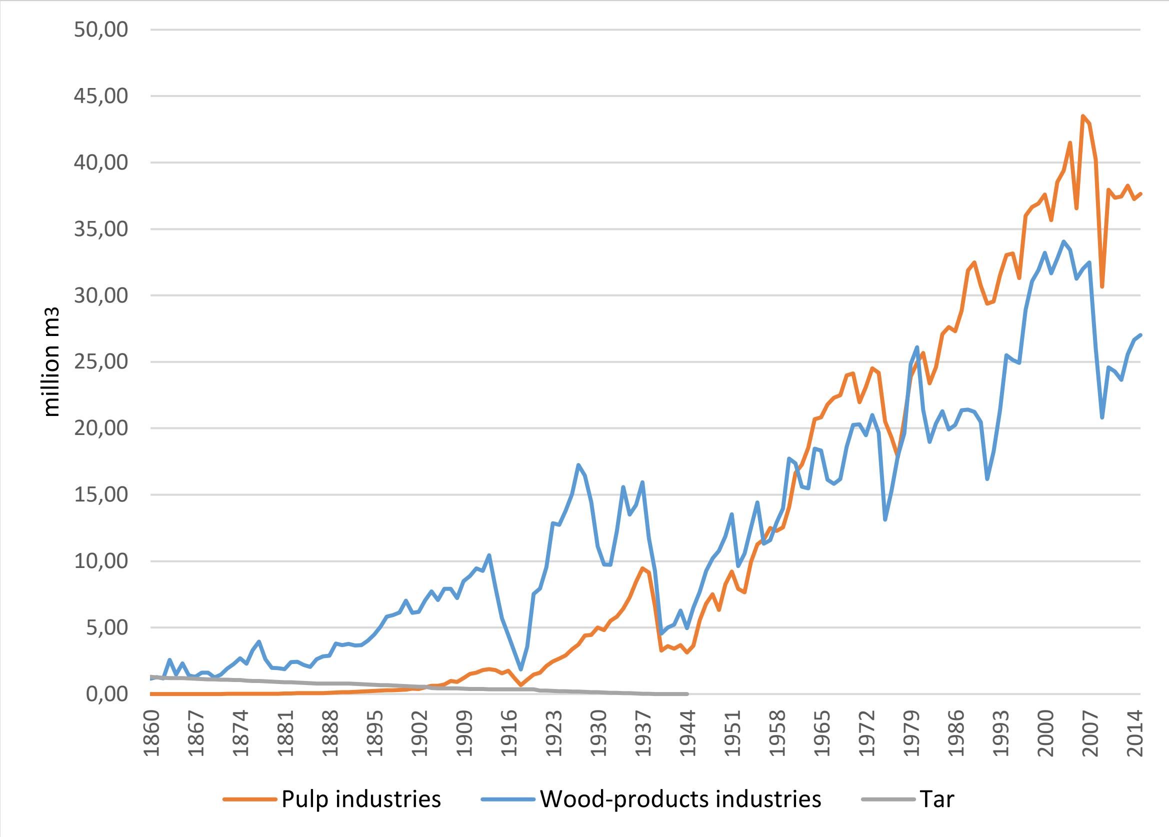

Figure 4: The wood consumption of the Finnish forest industries in between 1860-2016 (Luke 2017a) (Kunnas 2007).

Figure 4 contributes how tar-burning consumed significant amount of wood in the 1860s, but couldn't compete with other industries, and disappeared until Second World War. More productive wood product industry overdriven tar-burning and played dominant role until the WW II. After The Independency (1918) and Continuation War (1944), wood consumption of the pulp and wood product industry started to increase until 2007, when the growth stopped. Following sections outlines more specific details of the transition in production.

3.1.1 Wood product industry

Traditional sawing was based on inefficient and inaccurate handwork. Productivity multiplied when technology and techniques of sawing developed. In contrast to tar production, technology had a significant role in sawing. (Leppälä 2012, 281) In Finland, first water powered sawmills were built in the 1530s. Production did not increased a lot, because it took a long time to saw with a one blade. (Helander 1948, 57) In the 18th century there were many of modern sawmills, especially in Hamina where the mills used Dutch techniques in the 1730s. Sawmill, pulp and paper industry developed a lot in the 1850s (Finnish Forest Industries 2008). Finland was developed from pre-industrial agrarian to industrial society (Leppälä 2012, 289).

Electric sawmills run over steam powered sawmills in the 1920s. Power, rotational speed and blades were improved, which increased resource efficiency. Saws were faster than ever and drying methods transformed to artificial. There were also better focusing on maintenance. (Sipi 2002, 11) SFS- standards introduced in 1924 and A4-paper size got own standardization in 1927 (SFS 2017). Wood impregnation against decay started in the 1930s (Finnish Forest Industries 2008). Chlorophenols use gave 100% cover for fresh timber against blue rot, which founded on researches in 1933 and 1934 (National Board of Waters 1985). Sawmill industry used to be the biggest exporter by value until 1929 (Sierilä 2010, 14). In the 1950s, especially primary production had huge changes in the working techniques; a saw changed to chainsaw, a brook shovel to dynamite and a billhook to brush saw. Wood were transported to mills by car instead of horse, even though third quarter of the raw wood transported by log floating in the 1930s (Paaskoski & Virtanen 1995, 4,73). In the 1930s it was possible that wood transportation took 1.5 year from a forest to owner, whereas in the 1970s transportation took about 4 months. (Ahvenainen 1984, 414)

Automation accelerated production due to LASER in the early 1960s, which allowed better resource efficiency; it did not produced sawdust and noise or needed blades (Loukola 2001, 120). Automatic measurement devices became common in the end of 1960s, which allowed mark for cutting into lengths by harvester with a computer (Ahvenainen 1984, 414) (Tuominen 2011). For the wood moisture content, typical devices utilized electrical conductivity and infrared (Tuominen 2011). Motors moved logs in sawmills, and mechanization appeared as a line development. Frame saw was the main saw type until the end of the 1970s, when chipping canters and bandsaw became common. One trimmer were changed to trimmer units with optic measurement. (Ahvenainen 1984, 415) Dimension and quality based smart sorting with impulses developed in the 1970s (Ahvenainen 1984, 416). In modern sawing technology, sorting were done by light-based, 3D technology with digital cameras, and X-ray, which notice very small damages in the wood (Tuominen 2011). Drying facilities with automation and adjusted moisture content allowed fast drying. (Ahvenainen 1984, 416). Simulation of drying allowed to remark information about cracks, time of drying, and possibility to choose final moisture content. Sensors and computers use to make layout planning for the better resource efficiency. (Tuominen 2011) CNC-machines became common in wood working production in the 1980s (Loukola 2001, 100). The machines of Finnish forest industry used to be low age compared to competitors (Seppälä 2000, 11). The production volume of sawn goods and wood panels in between 1955-2017 is presented in Figure 5 (Luke 2018b).

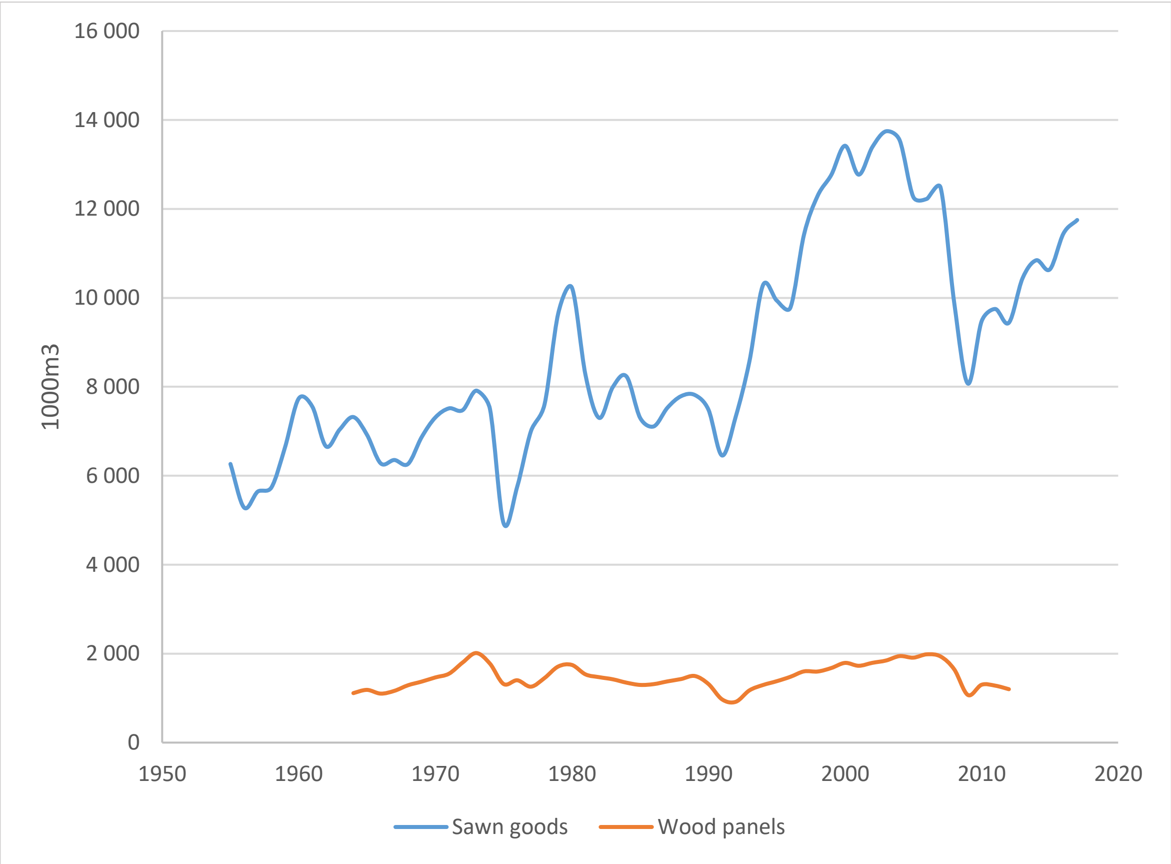

Figure 5: The production volume of traditional wood product industry (Luke 2018b)

Figure 5 outlines how the production volume of sawn goods increased fast in the 1990, whereas the production volume of wood panels has been flat. There has been large-scale development program of the sawmill industry since the 1990s (Poutanen 2000, 100). Significant investments in wood product industry, especially extension of refinement has improved after the 1990s due to new challenges of increased competition and institutional transformations (Lammi 2000, 15) (Metla 2010). The processes of wood product industry has become highly automated, but still operational models have been similar for the last decades (Ammattinetti 2018) (VTT 126, 2013). Especially sawmill industry has concentrated to big volumes and minimizing costs, and similar features have been in other wood product industry sectors (VTT 126, 2013). Until the 1990s neglected technology development in the sawmill industry production led to market position loss (Seppälä 2000, 53) (Poutanen 2000, 100).

3.1.2 Pulp and paper industry

Papermaking from linen rags started in the 1660s, and first paper mill launched in 1667. First paper machine launched in 1842. (Finnish Forest Industries 2008) Wood based papermaking from a mechanical pulp started in the 1860s, whereas chemical pulp production started decade later (Sierilä 2010, 13). Pulp and paper industry had technical problems and bias, and paper users thought that paper made from mechanical pulp is not strong enough. Demand of knowledge in the pulp industry was next level compared to the sawmill industry; Finnish bought technology from international companies due to technological basic structure was not able to find the answers to technological problems before the becoming independent. (Leppälä 2012, 285) Paper production from wood fibers were important advancement for the national economy (Finnish Forest Industries 2008).

Technological improvements increased the efficiency of pulp production. According to Huuskonen et all. (2013) studies, chronicle is missing in many sector. Sulfite process replaced by sulfate (Kraft) process in chemical pulp production. Sulfate process allowed better quality of pulp, higher chemical recovery rate and it was more environmental friendly. (Niemi 2013b) Pulp and paper factories equipped with process computers, area density and moisture controllers (Huuskonen 2009). Pulp production used to be highly self-sufficient by utilizing components efficiently. Tall oil side production launched in 1940, when distilling of tall oil from raw turpentine started for replacing lubricants. First reactors were build from bricks, but later automated reactors became common. Pine soap production started in 1953. (Niemi 2013). There have been a lot of academic development, practical knowledge and patents related to tall oil production (Pohjakallio 2015). Numerous amount of Finnish technical innovations in pulp production, e.g. barking, hacks, conveyors and storage improved water economy, quality and wood due date. (Huuskonen et all. 2013) In the middle of the 1970s oil and oil based raw material prices increased that affected to paper production. Companies innovated new processes, e.g. technique called Jylhä with heat recovery system and pressure grinding process for mechanical pulp, which allowed better strength. Versatile line allowed adapting to markets and independent use of wood species. Medium consistency (MC) technique allowed centrifugal pumping and mixing, which decreased water and energy consumption. Environmental protection required improvements in flue gas treatment, and scrubbers with heat recovery replaced direct flue gas treatment system. (Huuskonen et all. 2013). Domesticity rate of inputs in pulp and paper production has been high, almost 90% in the end of 20th century (Lammi 2000, 8). In the 2010s, in addition to process innovations, there have been also alternative innovations related to user-driven business, e.g. coffee cups' lid tower, which increases the use of compostable lids (Tekniikka & Talous 2018).

In 2017, Finland got a big bio-product mill to Äänekoski, and there are plans for the world biggest pulp mill to Kuopio. These so-called biorefineries utilize side streams and life cycle thinking, but processes are similar compared to traditional pulp mills (Aino 2016) (Ranne 2015). In biorefineries, incremental innovations have improved production and increased yield. In addition, flue gas and wastewater treatment systems have improved (Ranne 2015). The production of pulp and paper industry in between 1955-2017 is presented in Figure 6 (Luke 2018b).

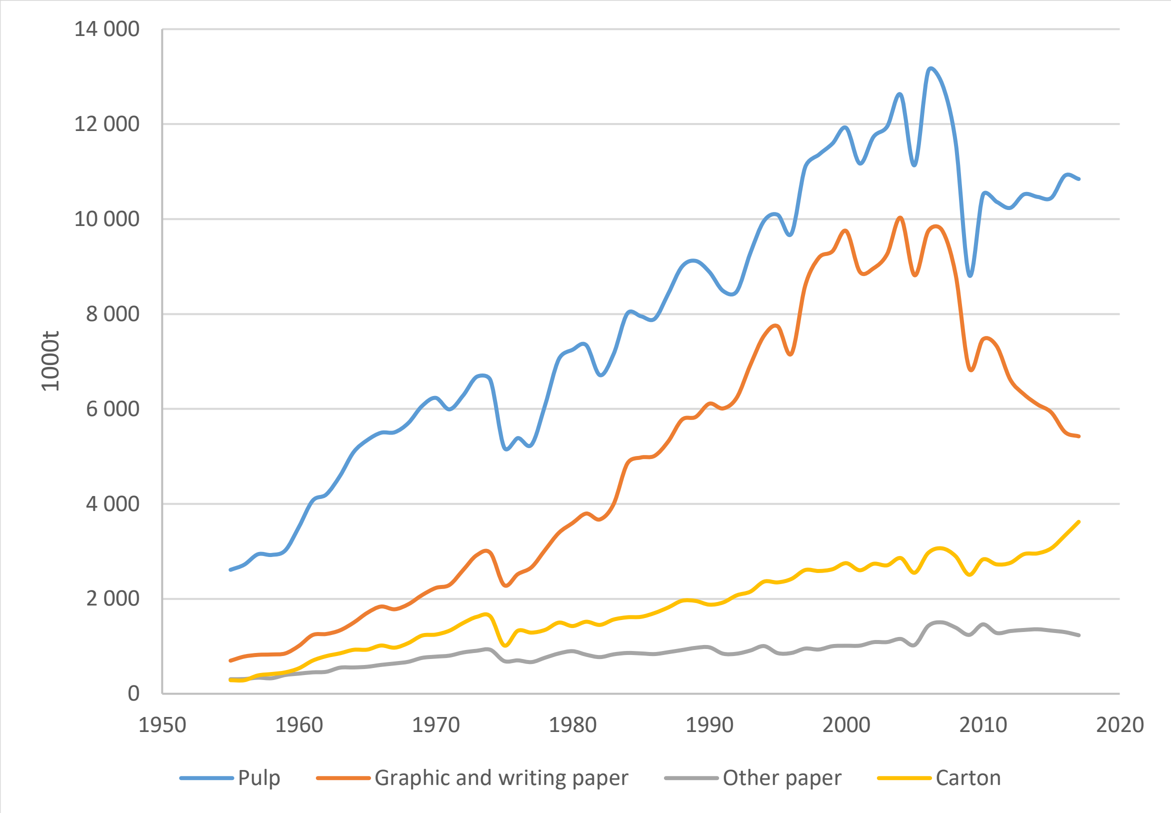

Figure 6: The development of pulp, paper and carton production (Luke 2018b).

Figure 6 contributes how graphic and writing paper production have increased until 2004, whereas other paper and carton production have increased slightly. Office work and IT increased paper consumption. Paper and carton consumption quadrupled in between 1950-2010. (Huuskonen 2009) (Finnish Forest Industries 2017b) So called bulk material production changed due to huge investments to new technology in the 1980s (Kuisma et all. 2014, 41). In the end of 20th century, digitalization and changes in behavior have affected paper and carton markets, and especially traditional graphic and writing paper demand have decreased (Finnish Forest Industries 2017b). Low profitability and high costs have affected also pulp industry (Suomen Kuvalehti 2008). There were lack of paying attention to consequences of digitalization in paper production (Uusi Suomi 2008). Since the 2010s, paper production has stopped in central Finland and based on coastal areas (Aino 2016). Carton demand has increased due to internet and increased packaging material consumption via online stores (Finnish Forest Industries 2017b) (Hämeen sanomat 2018). In addition, higher degree of living in Asia have increased carton demand (Hämeen sanomat 2018). Transition has forced to increase competitiveness with industrial consolidation and international investments. (Suomen Kuvalehti 2008) (Zhang et all. 2014) Vertical integration and globalization of the markets have been part of the transition, which is one reason for 10 000 lost employments since the 1990s (Sinclair & Walton 2003) (Aino 2016). Even the production has been profitable, forest companies have closed mills for giving raw material for the mills that are more profitable (Suomen Kuvalehti 2008)

3.2 Transition in product portfolio

In the early 19th century, there were regions for the different wood treatment actions. Coastal areas used to run sawmills, and next region further inner land used to refine tar by burning. Behind the tar-burning region, people used to do slash-and-burn agriculture. (Helander 1949, 23) (Sierilä 2010, 13) Tar production has decentralized, because manufacturing process was easy and trees transportation costs were high (Leppälä 2012, 278). In the end of the 19th century, construction of wooden ships decreased due to ships made by metals, which meant decreased demand of tar. Production costs were too high for competition, even though the government advanced to use more efficient tar oven, which produced also turpentine and allowed use of stumps instead of logs (Kaleva 2003) (Paaskoski & Virtanen 1995, 112). In the 1890s Finland had almost 40 tar factories, but soon half of them had to stop production due to unprofitability (Paaskoski & Virtanen 1995, 112). Industries wood demand grew and raised the value of wood so much that it was more profitable to sell wood straight from the forest (Hilden et all 2013, 53). Wood industry also offered jobs in factories and harvesting companies. (Hilden et all 2013, 53) In practice tar production disappeared until WW2. (Kaleva 2003) The most traditional products, high value bio-products and the total added value of forest industry in between 1900-2016 are presented in Figure 7. Start of production in traditional forest industry products is estimated if possible. Soft grey presents before the 20th century manufactured products.

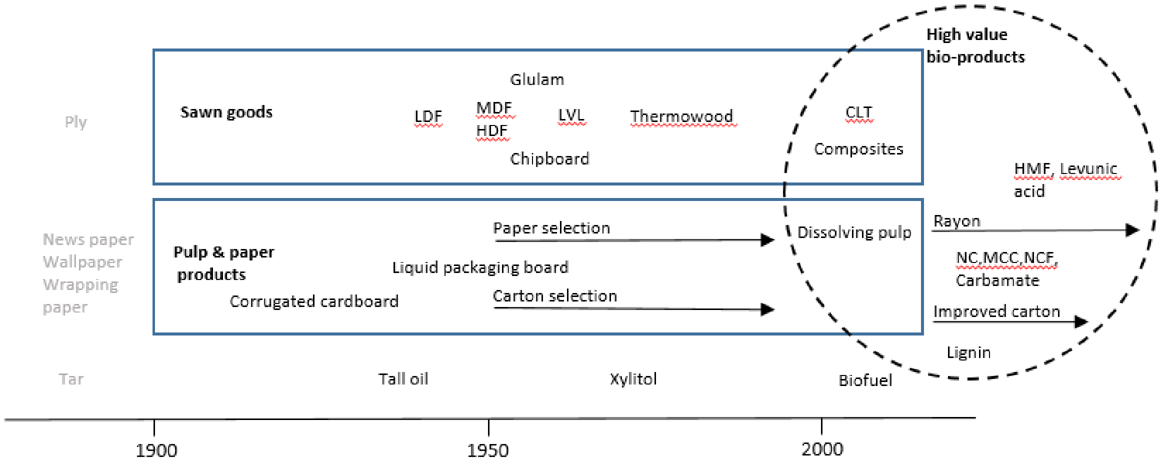

Figure 7: The product portfolio in the forest industry transition in Finland.

Figure 7 outlines that the most of traditional forest industry products have innovated around the 1960s, and improved until the 21st century. Many of high value bio-products are innovated as an extension of pulp and paper products. The added value increased in the all most important production sectors in the first half of 20th century (Laurila et all. 1968, 6). Until the end of the 1970s, forest sector used to grow economy by increasing loggings and basic investments, whereas new strategy included economy growth by adding value (Seppälä 2000, 7). Finnish forest industry invested a lot in the 1980s, and so-called bulk production changed due to modern technology (Kuisma et all. 2014, 41). Later in the last decades, productivity of forest cluster has typically increased by improvements in material balance, recycling and cheaper inputs. The bioeconomy has improved by user-driven technology, product and service innovations (Finnish Forest Industry 2009). Globalization of the forest industry has lowered costs but also increased competition due to cheaper transportation, lowered economic barriers, e.g. tolls and freedom of capital (Lammi 2000, 28-29). In the 2010s, product portfolio of the forest industry is based, and will most likely based on traditional products that added value is low (Prime Minister’s Office 16/2017). In 2017 gained profit by product selection has less significant than increase of wood use (Prime Minister’s Office 16/2017).

Importance of sustainability aspects increases in the value creation opportunities of industries (Korhonen 2016). Innovations and user-driven business are necessary for success of the forest industry (Hänninen 2013). Biggest potential of bioeconomy is in new technologies and products (PTT 2017a). Combining know-how and blurring frameworks that limits innovations are highlighted in product development (Niskanen et all. 2003). Change in consumer's behavior is important for increasing bioeconomy (Prime Minister's Office 16/2017). Wood demand will include ecological value (Niskanen et all. 2003). In addition, networking and efficiency of innovation process will be highlighted (VTT 2006).

3.2.1 Wood product industry

Quality of sawn goods improved by gluing parts together in 1893, when first plywood mill was built. (Poutanen 2000, 100) (Sierilä 2010, 13). Finland had many of carpenter, matchstick and spool factories in the end of the 19th century. Industrial wood usage increased fast and passed small-scale use in the 1910s. (Paaskoski & Virtanen 1995, 36,110) Low-density fibreboard as known as chipboard (LDF) production started in 1956. Glulam production started for the construction industry in 1958. Wood product was not dependent on size of tree anymore. In addition, glulam allowed new shapes, damage balancing and mixing wood species in different parts of the product, e.g. beech in compression side and spruce in pulling side. Glulam had better endurance against corrosion compared to steel. (Vesanen 2014, 8) In the 1960s wood based panels became general and especially chipboard was common in production (Luukkonen 2011). Laminated-veneer-timber (LVL) researches started in the early 1970s (Levonen 2016). Thermowood production started in the late 20th century. Cross-laminated timber (CLT) became Finland in 2014. CLT had many benefits compared to traditional construction. (Kekäläinen 2015) (Puuinfo 2018) Rate of added value of CLT production was less than 2 in Finnish projects in 2014 (Helamo 2014). User-driven operational models and services have increased in traditional industry sector (VTT 126, 2013). The total added value of wood product industry in between 1975-2016 is presented in Figure 8 (Luke 2016a).

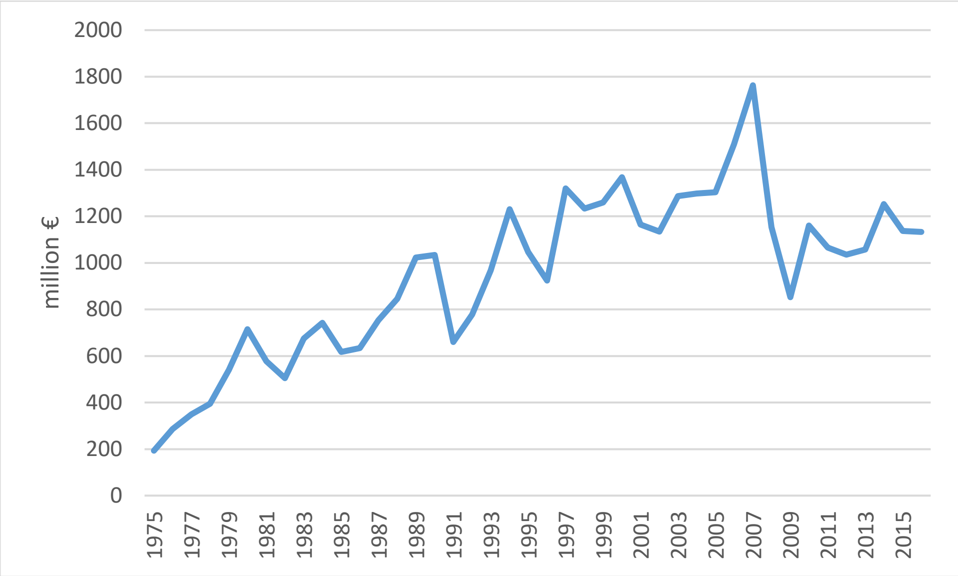

Figure 8: The total added value of wood product industry (Luke 2016a).

Figure 8 contributes how the total added value of wood product industry has increased until 2007, when it decreased rapidly one third. In between 2000-2007 during the increase, the efficiency rate of production was over 80% in the sawmills, and there were not significant changes in the efficiency. High bulk production due to low added value is one reason for the decreased competitiveness. Profitability has been low despite of huge raw material resources and modern production technology. (VTT 126, 2013) On the other hand, success of Finnish forest industries is based on profitable bulk production, and decrease is due to lack of product range (Häggblom 2014).

3.2.2 Pulp and paper industry

Wood based papermaking from mechanical pulp for a newspaper, wallpaper and wrapping paper started in the 1860s (Niinikoski 2010). Pulp based corrugated cardboard production started in 1911 (Seppälä 2013). Fiber based liquid packaging board production in the early 1950s, which became three-dimensional later (Salste 2011) (VTT 2017). Cartonboard (FBB,WlC,SBS,SUS,LBB etc.), coreboard, drywall, wallpaper board and bookbinding products have diversified product portfolio. Product can be designed individually in between producer and customer. In the 1990s green way of thinking grew up, and cheaper deinked pulp became common. (Salste 2011) A common trend have blurred frameworks in between paper and paperboard in general, and its characterization is based on end use since the end of the 20th century (Karhu 2007) (Huuskonen 2009). Growth of product outcomes in the P&P industry have been stable for a long time (Novothy & Laestadius 2014). Some of the forest companies' strategies includes user-driven product development (METSÄ Group 2017). The total added value of pulp and paper industry is presented in Figure 9.

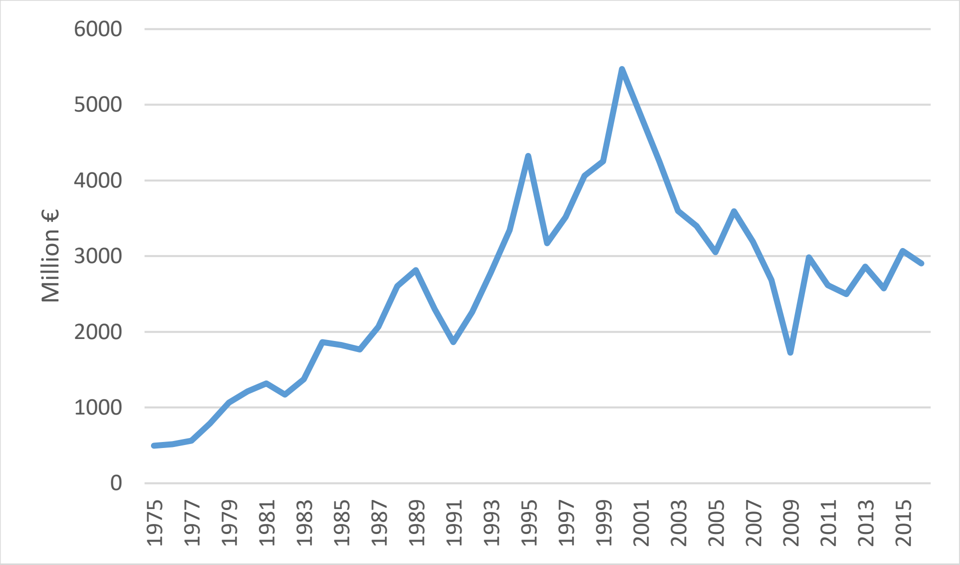

Figure 9: The total added value of pulp and paper industry (Luke 2016a)

Figure 9 contributes how the total value of pulp and paper industry has decreased since 2000, and stabilized since 2010. Mistakes of investments bills to capacity in the beginning of the 2000s, lack of R&D and decrease in graphic and writing paper demand have affected to situation (Uusi Suomi 2008) (Suomen Kuvalehti 2008) (Hämeen Sanomat 2018). Exchange rate, price of energy and export tolls have been more marginal reasons for the decrease (Suomen Kuvalehti 2008). The remits of paper production have been most weak parts of the forest cluster, because low domestic use could not create good relation in between producer and user. For comparison, machine workshops have created intensive relation in between producer and user in the Finnish forest cluster. (Lammi 2000, 13-15) In the last decade, pulp has exported to other countries for extending refinement (VTT 2017). In 2017, pulp exports accounted 3.75 million tons that is 49% of total produced pulp (PTT 2017c) (7,7 million tons) (Yle 2018). The pulp exports in between 2009-2018 are presented in Figure 10.

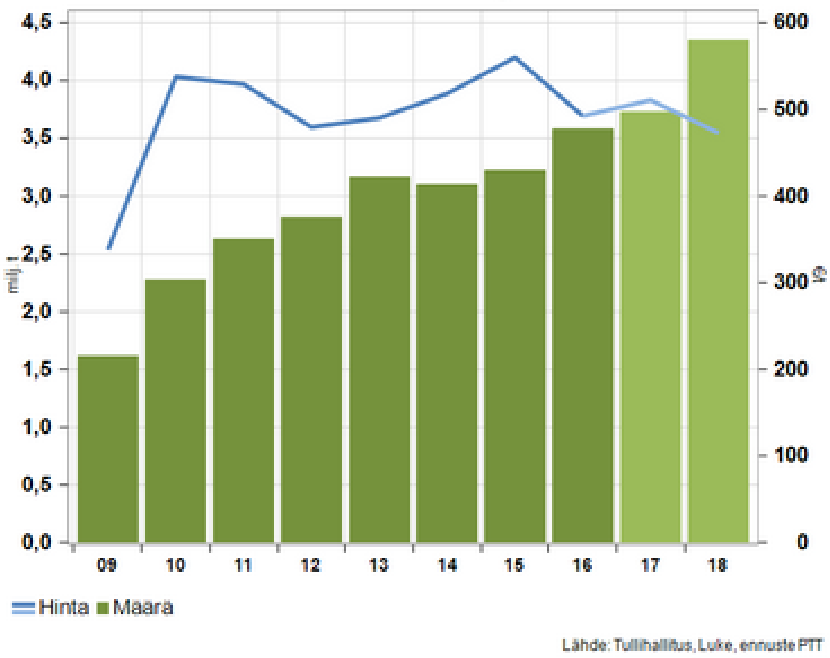

Figure 9: The pulp exports and price of pulp (PTT 2017c)

Figure 9 outlines how the pulp exports have increased in the last decade. In 2018, increase of pulp exports continues, especially due to Äänekoski biorefinery that export to China most of its products, even the price of pulp will decrease due to currency rate of euro in relation dollar (Kauppalehti 2018) (Maaseudun tulevaisuus 2017a).

3.2.3 High-value bio-products

Rayon production from wood fibers started in small-scale in the 1930s. Dissolving pulp production for textile fibers started in the early 1980s, but the production stopped over 20 years due to increased pulp demand for paper manufacturing. Wood based textile fibers seems to be one of the potential future raw material for clothes, e.g. Ioncell-F (Aino 2016). Stora Enso is starting to produce dissolving pulp for textiles in Uimaharju (Maaseudun tulevaisuus 2017b). New products made from wood fibers can double added value, and it is possible, that rayon can compete against cotton by price and environmental aspects (VTT 2016b) (Hilden, Soimakallio 2016). In addition to textiles, specialty grades of dissolving pulp can be used in car tyres, nitrocelluloces (NC), microcellucoces (MCC), films, toothbrushes and diapers, which include high value. (Viitala 2016) Cellulose based diaper has 30% better absorption capacity than incumbent product (VTT 2017). Cellulose carbamate is tens of percent more valuable than pulp, and when cellulose carbamate powder is transformed to fibers, the value doubles (VTT 2017). In addition, AaltoCell might have potential for cows supplement (Aino 2016).

Microcelluloce is used for example in medicals for a long time, and Stora Enso has invested for accelerating microfibercellulose commercialization in Imatra (Aino 2016) (Yle 2017a). First nanocellulose patents announced in the early 1980s, but high costs have slowed the production. In 2014 announced national bio-economy strategy concludes that nanocellulose is nationally important for Finland. Nanocellulose has specific properties related to rheology, and it has better strength than any synthetic fiber reinforcement (Yle 2017a). There have been a numerous amount of potential applications and pilot projects for nanocellulose, e.g. paint, grocery, and medical production, adding strength in composites and packaging materials, improving barrier properties in packaging and replacing plastics (Yle 2017a) (VTT 2014). According to Thaddeus Maloney, Professor of Bio-based Material Technology at Aalto University, biggest challenge related to nanocellulose is creating something new that other materials could not compete (Yle 2017a).

Tall oil refinement started in the 1910s (Pohjakallio 2015). Distilling of tall oil from raw turpentine for replacing lubricant started in 1940. Pine soap production started in 1953. (Niemi 2013) Tall oil is used in car tyres, glues, gums, lipsticks, anti-bacterial feed and compounds that increase the asphalt-recycling rate. Modern tall oil plant can produce sterols for functional groceries and paint products. (Pohjakallio 2015) Lignin can replace phenols in glues and used in carbon fiber, biochemical and biofuel production (Harlin 2017). Crude tall oil (CTO) can be refinered to tall oil fatty acid (TOFA), tall oil rosin (TOR) and tall oil pitch (TOP), which are used in biofuels (Näsi 2010).

Xylitol researches launched in 1970 and products released in the 1980s (Graviola 2011). Cells have grown in nanocelluloce, and extracted docetaxel from yew has used in cancer medicines (Rautiainen 2017) (Yle 2017b). Wood based biodegradable packaging material is potential competitor against plastic (Biotalous 2017) Xylan, fibrillated celluloce and lignin allows improvements in groceries by improving quality and healthiness (VTT 2016). Chemicals, e.g. furfural, HMF and levunic acid can be produced from lignosellulocic materials by hydrolysis, pyrolysis and gasification (Vanninen 2009) In addtition, wood-plastic composites have used in furniture and goods (Tulevaisuusvaliokunta 2013).

"Everything that's made with fossil based materials today can be made from a tree tomorrow"- Stora Enso 2017

Competitiveness of the forest industry will be based on high value products rather than bulk production (Hänninen 2013). High-value products such as fibers, chemicals and wood construction have usually higher added-value compared to e.g. biofuels (Hilden, Soimakallio, 2016). Wood-based materials can replace fossil-based materials (VTT 2017), and some of the wood-based bio-products seems to include higher performance compared to similar fossil-based products. Woodworking technology together with chemistry have been in significant role while developing diverse wood treatment processes (Lammi 2000, 93). In addition, services can increase the added value of forest industry (Hänninen 2013). On the other hand, some of new business ideas and technologies related to biorefinery development have been outside of the actual competence. There has been a resistance of change related to biorefinery development, which automatically lowers innovation search related to bio-products. In addition, lack of funding and low investment capability have affected to biorefinery development. (Hämäläinen et all. 2011)

3.3 Transition in organizations

During the past two centuries, forest policy regime has changed regarding to sustainable forestry, development of technology, international trade, ownership of institutions and forestlands, legislation and positions (Kotilainen & Rytteri 2011). Economic-political special status has been significant part of the success of Finnish forest cluster, but its magnitude has decreased. (Seppälä 2000, 11). Associations have supported the development of forest industry especially after the becoming independent. In addition, research and education have pushed technology and innovations towards more efficient forest utilization especially since the mid 20th century.

3.3.1 Policy

Overproduction of sawmills supervised by officers already in the 1640s (Helander 1949, 60). Cooperation in sales with Old Finland (Area under Russia 1721-1812) created the base for Finnish forest industry development and Saimaa Canal. Catherina the Great offered interest-free loans for sawmills and allowed unlimited and duty-free sawn good exports since 1747. Viipuri province had only 5 small saw mills in the early 18th century, but in the end of century it had 52 sawmills. Forest industry development in Old Finland is a good example what happens when guidelines fails. (Helander 1949, 62) Until 1857 steam powered sawmills were illegal in Finland. A few years later limitation of sawing were removed and British got rid of duties in timber. Due to the previous decisions, Finnish wood production tripled in the 1870s. (Sierilä 2010, 13) Forest administration established in 1858, and The Finnish Forest Service (Metsähallitus) launched a year later (Kotilainen & Rytteri 2011). Industrially minded politicians and foresters started to fear deforestation, and first time in 1886 committees proposed law for private forestry, which set limitations for logging and standards for regeneration (Kotilainen & Rytteri 2011). Companies bought millions hectares of forest areas and tried to take over forest resources from the beginning of the 1890s, but later land reform limited industrial ownership in the 1910s (Kuisma et all. 2014, 9). The law limited companies' landowning in the 1920s, but it was possible to buy land from daughter companies (Laurila et all. 1968. 34). Companies got export tolls in the 1920s (Laurila et all. 1968. 35).

The forest industry became a huge political issue, because of the forest sector accounted 90% of the total exports at the beginning of the 1920s and 80% in the 1950s (Kotilainen & Rytteri 2011) (Aino 2016). Incorporation of the government owned companies accelerated industrialization in the 1920s, and independent government purchased shares of Enso-Gutzeit company and started to create wealth for the nation (Kotilainen & Rytteri 2011). Government owned companies were launched for the better economy, which private sector could not do. (Kuisma 2009, 168) Subsidies for companies and private sector became into effect in 1928, when The Forest Improvement Act allowed more raw material for the industries (Kotilainen & Rytteri 2011) (Laurila et all. 1968. 8). The government offered grants and loans for improvements, e.g. drainage of peat lands and afforestation. The government managed industrially important wood species growth by banning private forest owners practiced selective cutting until the 1920s, when selective felling methods became illegal. Geobotanist A.K Cajander, Professor of Forestry at the University of Helsinki, chairman of the board of the Forest Research Institute, chairman of Enso-Gutzeit’s administrative board, chairman of the Finnish Society of the Forest Science and since 1918 Director-General of the Forest service, was infuential actor in forest sector. (Kotilainen & Rytteri 2011). Forest administration was reformed, loggings were increased and forestry was improved under A.K Cajander (Metsähallitus 2015). Forest knowledge in politics was negligible (Laurila et all. 1968. 37). Some of the politics argued that tighter private forest control secures sustainable use (Kotilainen & Rytteri 2011). There has been idea that supply creates demand, which meant that the more timber was cut, the more robust process industry would be – in effect creating wealth. (Kotilainen & Rytteri 2011)

One third of the war reparations have paid by Finnish forest industry. Finland lost 12% of the forest area due to reparations. (Sierilä 2010, 15) The refugees needed land for agriculture that meant forest transformation to fields. This caused very intensive model of industrial forest utilization for guaranteeing raw material inputs for the forest industry. (Kotilainen & Rytteri 2011) Reparations accelerated mechanical industry, and forest cluster started to born (Finnish Forest Industries 2007). Increased and diversified Finnish forest industry modified energy policy in the 1960s, and it was more profitable to refine wood products instead of burning and buy cheap fossil fuels for energy. Burning of wood regarded to be irresponsible. (Hilden et all 2013, 58)

Environmental consciousness raised up, and biodiversity became a part of forest policy after the UNCED in 1992. Legalization of unlimited international ownership since 1993 modified legislation for helping forest industry decline in business activity. International ownership of Finnish forest industry companies were increased to 60% by 1999. (Metsäteollisuus ry & Paperiliitto ry 2006) (Kuisma et all. 2014, 131) National capitalism were stopped and Finland joined EU in 1995. Barriers of internalization and national markets were gone. (Kuisma et all. 2014, 133) Forest industry used to have strong affect to exchange rate policy, but after joining EMU, the influence decreased (Seppälä 2000, 12). The Forest Act promoted economically, ecologically and socially sustainable use of the forest in 1996. (Kotilainen & Rytteri 2011)

LULUCF, biofuel and RED have been the topics of forest industry discussion in the 2010s. LULUCF set by EU has given limits, and on the other hand, allowed more intensive wood use for the forest industry (Klimaatti 2017). LULUCF is included the part of climate policy since 2021 for achieving climate targets (Romppanen 2018). Biofuel investments have had benefits by double accounting method set by EU, which will end in 2020 (Tekniikka & talous 2017). RED I & II, set by EU, have included 14% aim for the biofuel use in 2030, but the national target is 30% in Finland (Ministry of Agriculture and Forestry 2018). Wood construction industry and energy sector benefits Climate Agreement (Niskanen et all. 2003). In the 2010s Finnish policy has been framed as “more of everything”, which has expressed as more productivist and less deliberative solutions (Kröger & Rautio 2017). According to Kotilainen & Rytteri (2011) “ As in the past, prominent actors have introduced new elements into the institutionalized industrial model to secure its existence”. The focus of forest and industrial policy has been more on slowing down than creating new. Acts have concentrated to operations of forest supply and transportation infrastructure, rather than diversifying of forest sector. (Hetemäki 2009) Finnish government national plan for 2020 includes wood product diversification and value addition that increases economy, employment and exports by launching innovation, research, pilot and demo activity for accelerating commercialization. (Finnish Government 2018)

3.3.2 Associations

Economic nationalism and internationally powerful cartels were part of the Finnish forest industry in between World Wars (Finnish forest industries 2007). Central Association of Finnish Woodworking Industries (CAFWI) launched for taking care of politic-economic interest in 1918 (Laurila et all. 1968. 11). Loss of markets due to independency led to companies’ cooperation and market search (Laurila et all. 1968. 6). CAFWI included Finnish Sawmills Owners’ Association, Finnish Paper Mills Association (Finnpap), Finnish Groundwood Association and Finnish Chemical Pulp (Finncell) Association. First rules of CAFWI did not gave chance for other societies or associations for joining. (Laurila et all.

1968. 22). It can be said that CAFWI was originally defensive economic-policical union, which born in situation, when there was silliness, prejudices and fast changing economic environment (Laurila et all. 1968. 71).

Sale unions Finnpap, Finncell, Finnboard and Converta combined, which decreased competition. Finnish companies together were big actor in the western markets, which helped economical recover. First timber related cartel founded at the middle of the 1930s. European Timber Exporters' Convention (ETEC) set production limitations and minimum prices. (Sierilä 2010, 14) Government protected cooperation culture, neither "cartel" was not a swear word (Kuisma et all. 2014, 135). The CAFWI's research unit Metsäteho launched a project with side holders for improving wood working methods and use of machines in production in 1945 (Laurila et all. 1968. 22). Price of wood has been decided by Central Union of Agricultural Producers, Finnish Paper Producers Association and Forest Owners, Finnish Pulp Wood Association and Metsäliitto Oy since 1960s (Kuisma et all. 2014, 77). Building of new mills was not easy for cooperative societys in the 1970s, because practically investments needed permission from Bank of Finland and the CAFFI (Kuisma et all. 2014, 30).

Forest Stewardship Council (FSC) launched originally for a tropic plantations by initiative of WWF in the early 1990s. Later forest owners in Europe launched Programme for the Endorsement of Forest Certification (PEFC), because FSC could not response challenges of small-scale forestry. (Kotilainen & Rytteri 2011) In 2016, over 90% of the forest area in Finland has PEFC certification, whereas only 6% has FSC certification. The rules are based on national standards, which not guarantee sustainability and biodiversity aspects. (MTK 2016) The rules of PEFC have not been as strict as FSC concerning to ecological questions (Kotilainen & Rytteri 2011).

3.3.3 Research

Research and technical education used to be dispersed and simple before the independency, but quality increased slowly all the time (Leppälä 2012, 285). Technological knowledge was low, and higher company level headmen did not trust in Finnish engineers in the pulp industry before the becoming independent (Leppälä 2012, 285). In the 1910s paper industry got own publication paper that focused on technical problems, whereas the sawmill industry did not have publication system. (Laurila et all. 1968. 21). First professorship related to sawmill industry was founded in 1926, and wood technology research institute launched in 1929. (Sierilä 2010, 14) Forestry professionals preferred forestry on large scale organized by state authorities, and they favored industrial ownership instead of peasants because they believed that companies use forest resources by sustainable way. (Kotilainen & Rytteri 2011)

Research work and consulting have increased the knowledge of Finnish forest cluster (Lammi 2000, 15). Universities, VTT and Metla have been significant research units in public sector (Lammi 2000, 21). Technical development of sawmill industry was slowly between Word War I and II. Technical laboratory of forest industry made researches concerning to strength and drying methods, and huge test sawing project launched in the early 1950s. In addition, private sector made innovative research work. (Ahvenainen 1984, 413) In the 1960s research work concerning to improvements and new techniques discovered how to improve forest performance by fertilizing, ditching and land modification. (Hilden et all 2013, 72) Technical Research Centre of Finland (VTT) launched for supporting Finnish industries' simple laboratory units in 1942. VTT tested products for war reparations and developed replacing products. Later in 1970s, VTT transformed from test department to one of the most significant technical research unit in Europe. (Leppälä 2012, 311) Finnish knowledge in mechanical and chemical pulp production has lured international companies for cooperation. Cooperation between pulp and paper workers, chemists and mechanical engineers has become more intensive. (Huuskonen 2009) Finnish Bioeconomy Cluster (FIBIC) Oy owned by the most significant companies, research units and universities has widened its practices to different bioeconomy sectors in the early 2010s (Tekniikka & talous 2012).

Innovation work in the forest industry has been disorganized and affected by contradiction in between targets; companies' need cost-efficient solutions quickly and sustainable reformation at the same time. R&D and targets concerning to cost-efficiency have led to practice, where innovations are typically small incremental process innovations whereas radical product innovations rises rarely. (Ranne 2015) (VTT 2006) Domestic consumers have had important role in the innovation process for decreasing time of product development. (VTT 2006) The direction of R&D has aimed by three big forest companies (Aino 2016). In the end of 20th century, R&D in forest industry has been around 0.5% (Lammi 2000, 21). 90% of the R&D funding is invested for pulp and paper products in the end of the 1990s and 2000s (Lammi 2000, 21) (UPM 2008). Talk and questions related to grievances of the bioeconomy can decrease funding possibilities due to institutional relations and Finnish funding system (Aino 2016).

4 RESULTS

The following sections outlines the returns of path-dependency, lock-in and TIC in the case forest industry transition in Finland. Figure 10 outlines increasing returns in the forest industry transition. The sources are not bonded to certain timeline or dimension, e.g. war reparations have set expectations towards more efficient forestry methods for industrial use and accelerated networking of forest cluster.

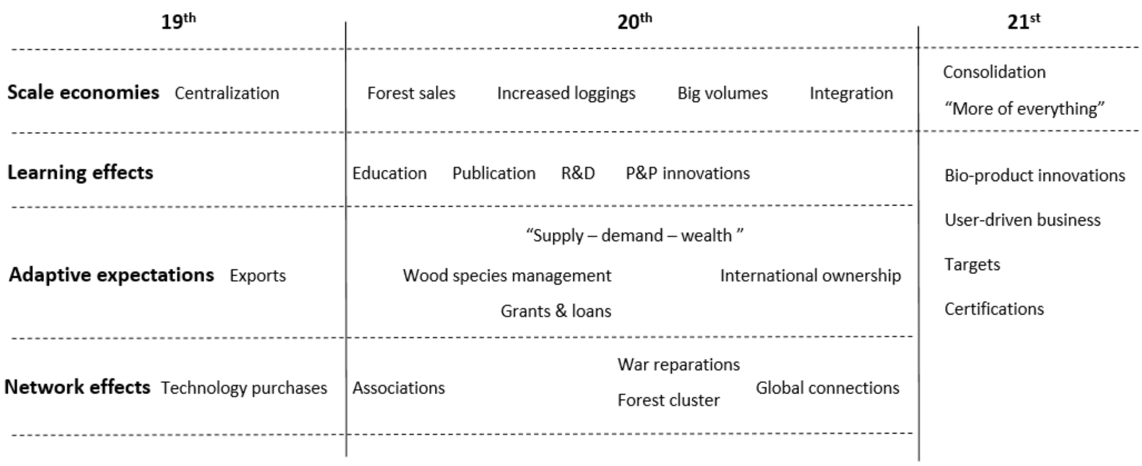

Figure 10: Increasing returns in the forest industry transition in Finland.

Figure 10 outlines how the present sources of increasing returns have blurred the frameworks of dimensions. Bio-products innovations, user-driven business, targets and certifications includes primarily the elements of learning effects, adaptive expectations and network effects. These multidimensional sources of increasing returns have connected to climate change mitigation and jobs creation. Sources such as consolidation and "more of everything" includes primarily the elements of scale economies. Capacity to increase returns have varied between different sources, e.g. integrations are limited, whereas returns by innovations can be seen as unlimited. The sources of increasing returns have been diverse in the forest industry transition.

Traditionally, the innovation search of forest industry has been path-dependent by lock-ins, but later diversidied product portfolio expresses the transformation of innovation search. Institutional, technological and industrial lock-ins have primarily increased returns in the forest industry transition, but e.g. blocking competitors have also decreased available returns. The elements of TIC in the forest industry have increased returns, which has occurred as creation of forest cluster. The active role of government in the TIC has allowed the actions of forest industry and increased returns.

4.1 Path-dependency

In the 21st century, multidimensional sources of increasing returns are identified in the forest industry. Finnish forest industry has improved bioeconomy by developing user-driven technology, which is necessary for the success of the forest industry (Finnish Forest Industry 2009) (Hänninen 2013). Directives and targets have affected to the returns of forest industry, e.g. biofuel investments have had benefits by double accounting method, and LULUCF have given limits and on the other hand, allowed more intensive wood use for the forest industry (Tekniikka & talous 2017) (Klimaatti 2017). Change in consumer's behavior is important for increasing bioeconomy (Prime Minister's Office 16/2017). Demand has included ecological value of wood (Niskanen et all. 2003) that companies have utilized, e.g. by following FSC and PEFC systems.

Scale economies have increased returns especially in the 20th century. Companies started to buy forest areas (Kuisma et all. 2014, 9), which allowed more constant and adequate raw material flows. Production used to be home industry until the 19th century, when decentralized production started to supersede by industrialization that first implemented by growing number of saw and pulp mills, but also continued until 21st century via industrial consolidation and vertical integration (Leppälä 2012, 277) (Zhang et all. 2014). Until the end of the 1970s, forest sector used to grew economy by increasing loggings (Seppälä 2000, 7). The sawmill industry has focused on big volumes (VTT 126, 2013). In the 2010s, policy has been framed as "more of everything", which has implemented as more productivist solutions (Kröger & Rautio 2017). In 2017, increase of wood use were more significant for gained profit than wider product selection (Prime Minister's Office 16/2017). On the other hand, forest industrial ownership and launching new sawmills have become limited (Laurila et all. 1968. 34), which have marginally decreased returns by scale economies.

Learning effects have increased returns constantly during the forest industry transition. Government, companies, private sector and associations, e.g. CAFWI have done researches towards more efficient forestry and wood working methods (Ahvenainen 1984, 413) (Laurila et all. 1968, 22) (Hilden et all 2013, 72). Later R&D have focused more on dominant pulp and paper product industry, which chronicle and information related to innovations are partly missing (Lammi 2000, 21) (Huuskonen et all. 2013). Professorships and forestry professionals favored large-scale forestry organized by state authorities and industrial ownership (Kotilainen & Rytteri 2011). First own publication paper of paper industry (Laurila et all. 1968, 21) increased spreading of technological knowledge between companies and institutions. Finnish forest industry has improved bioeconomy by developing product and service innovations (Finnish Forest Industry 2009). Innovations are necessary for success of the forest industry (Hänninen 2013). Combining know-how and blurring frameworks that limits innovations are highlighted in product development (Niskanen et all. 2003). Biggest potential of bioeconomy is in new technologies and products (PTT 2017a). In addition, efficiency of innovation process will be highlighted (VTT 2006).

Adaptive expectations have increased returns during the forest industry transition. Common idea that supply creates demand that creates wealth (Kotilainen & Rytteri 2011) has set expectations for the whole forest sector. In addition, the idea that burning of wood was irresponsible (Hilden et all. 2013, 53) allowed more raw material for industrial use. Forest industry products' high amount of exports, e.g. 90% in the 1920s (Kotilainen & Rytteri 2011) and interest of launched associations and sale unions in the early 20th century had set expectations concerning to exports. The government has managed industrial wood species and assigned grants and loans due to modifications in legislation for more efficient forestry methods (Kotilainen & Rytteri 2011). Lost forest areas due to war reparations and forest transformation to fields set pressure to more efficient forestry methods for industrial use (Kotilainen & Rytteri 2011). Legalization of unlimited international ownership (Kuisma et all. 2014,131) set expectations of investment money.

Network effects have increased returns especially in the early transition. Finnish pulp industry could not find answers to technological problems, and technology bought from international companies (Leppälä 2012, 285). Launched associations and their cooperation with institutions for example politic-economic interest (Laurila et all. 1968. 11) have increased network effects. Forest industry together with machine industry started to create forest cluster due to war reparations (Finnish Forest Industries 2007). The world's top-quality paper and pulp engineers educated in Finland have spread around the world (Huuskonen 2009). Networks of associations have increased, but also limited international returns by protectionism. CAFWI has decreased returns by banning other associations to join (Laurila et all. 1968, 71, 22). In the future, networking of the forest industry is highlighted (VTT 2006).

4.2 Lock-in

Traditionally, the innovation search of forest industry has been path-dependent by lock-ins. A numerous amount of innovations were created especially in the pulp industry, but there were lack of radical product innovations in the end of the 20th century. (Huuskonen et all. 2013) (Section 3.2.3) (Figure 7) Innovation search has aimed by three biggest forest companies (Aino 2016). 90% of the R&D funding were invested for pulp, paper and paper products in between 1990s and 2000s (Lammi 2000, 21) (UPM 2008). Innovations have been typically small incremental process innovations, and rarely radical product innovations (Ranne 2015) (VTT 2005). The diversified product portfolio has been the sign of transformation in the 21st century (Figure 7). A part of high value bio-products are innovated as an extension of pulp and paper products (Section 3.2.3). If new technology has not fitted company's practices, progression has been difficult (Yle 2016b). Talk and questions related to grievances of the bioeconomy can decrease funding possibilities due to institutional relations (Aino 2016).

Institutional lock-in has increased returns by intervention of government policy and making legal frameworks in the forest industry transition. In Old Finland, unlimited and duty free sawn good exports were allowed by policy practiced by Catherina the Great, which permissive legislation created the base of the forest industry to Eastern Finland (Helander 1949, 62). In the mid- 19th century, political decisions concerning to limitations, bans and duties tripled wood production in a decade (Sierilä 2010, 13). The forest cluster has benefit its economic-political special status (Seppälä 2000, 11). The forest cluster decision-making power in policy has been in big role, and it has developed institutionalized industrial models to secure its existence (Kotilainen & Rytteri 2011) The government has accelerated forest modification for industrial use and modified legislation that has benefit forest industry (Kotilainen & Rytteri 2011) (Leppälä 2012, 311). The forest administration was reformed and loggings were increased under A.K Cajander in the early 20th century (Metsähallitus 2015). Forest cluster's cooperation and cartel culture used to be protected by the government, especially in between World Wars (Kuisma et all. 2014, 135). Since 1993 the government has allowed unlimited international ownership of the forest companies (Kuisma et all. 2014, 131). Industry originates PEFC system allowed loosen rules compared to original FSC (Kotilainen & Rytteri 2011).

Technological lock-in has affected returns by cultural and economic advantages of dominant design and blocking competitors in the forest industry transition. Forest industry has been important employer, especially in counties, and its export incomes has been high for the centuries (Finnish Forest Industries 2018). Tar-burning used to be dominant design in the 19th century, but it lost its market for other materials. The next dominant design of forest industry was the sawmill industry that superseded by pulp industry (Poutanen 2000, 100). First rules of CAFWI did not gave a chance for other associations to join (Laurila et all. 1968, 71, 22). In cooperative society, new investments needed permission from the Bank of Finland and the CAFFI in the 1970s (Kuisma et all. 2014, 30). Paper and textile fiber industry have had competition of pulp, which caused end of dissolving pulp production for textiles due to pulp demand for paper industry (VTT 2016b).

Industrial lock-in has increased returns by technological interrelatedness, standardization and co-specialized assets in the forest industry transition. The forest cluster has included technological interrelatedness in many sectors, e.g. pulp factories produce adequate pulp for demand of paper factories that produce A4 paper for printers, and in the wood product industry, sawmills produce adequate blanks for panel production that is used in construction industry. Finnish companies got own standardization system in the 1920s (SFS 2017), and standardization has become necessary in many sectors. Nowadays standardization starts from the forestry. Co-specialized assets have occured, e.g. between the forest industry and the government, especially in the early 20th century, because the forest industry was the most important income for the country and the government made forest industry actions possible. There has been also smaller co-specialized assets inside the forest industry, e.g. sawmill industry have had co-specialized assets with construction industry.

4.3 TIC

The elements of TIC in the forest industry have increased returns. The forest industry has been important income for the government especially during the first half of 20th century, and it has offered jobs and products for the citizens (Finnish Forest Industries 2018). The forest industry has gained a lot of side industries and remits around of it that has created the Finnish forest cluster. It has gained positive externalities from internal cooperation and competition. (Lammi 2000, 13) More efficient technologies, especially in the pulp industry, has been actively innovated by Finnish forest industry with cooperative organizations during the 20th century (Huuskonen et all. 2013). The CAFWI (1918-1992) has been one of the most important cooperative associations, because it has included the most significant forest industry associations.

The active role of government in the TIC has increased the returns of forest industry. Arguments presented in the previous section (4.1.2) concerning to intervention of the government policy in the forest industry transition supports the claim. In addition, the government has been owner of the significant forest industry companies, practiced research work towards more efficient forest industry, accelerated forest modification for industrial use by grants and loans and modified legislation that has benefit forest industry (Kotilainen & Rytteri 2011) (Leppälä 2012, 311). Powerful people have worked for the research units, university, government and biggest forest companies at the same time (Kotilainen & Rytteri 2011).

5 DISCUSSION

This thesis has reached the aim by identifying the returns of path-dependency, lock-in and TIC and considering the lock-in of innovation search. The multidimensional sources of increasing returns are identified in the forest industry. These sources have blurred the traditional frameworks of increasing returns. The innovation search of forest industry has been path-dependent, but transformation has occurred. Novothy & Laestadius (2014) study concerning to lock-in case of P&P industry supports finding of this thesis. They found variation in different industrial transformation cases; almost complete escape from lock-in (papermaking paradigm), gradual change of product portfolio but new technologies (lignin, textile pulp) makes transformation possible and still lock-in of the papermaking. Their findings concludes how lock-in have varied between companies, and how companies have possibilities for transformation across the traditional framework.

The present multidimensional sources of increasing returns such as bio-products innovations, user-driven business, targets and certifications have included the elements of learning effects, adaptive expectations and network effect, and hence blurred the traditional frameworks. So far, there is no evidence that these sources have brought significant returns for the forest industry. Thesis calls further research to consider, how these sources can be utilized in practical for increasing returns in the forest industry. The bioeconomy has potential to double the returns (Hänninen 2013). In the future, wood demand will include also ecological value (Niskanen et all. 2003) that can be seen as a competitive advantage.

Traditionally, the innovation search of forest industry has been path-dependent; diversified product portfolio has been the sign of transformation of innovation search. That calls further research to consider how the innovation search can be improved and unlocked from the traditional forest industry framework for achieving more radical innovations for avoiding the elements of path-dependency and lock-in. Now is the best time ever for radical product-service innovations that leads sustainable cure of competitiveness and higher technological development (Yle 2017c) (VTT 2006). There is a contradiction between innovation research towards high value products and funding system. There are only a couple of big companies who could invest and push projects forward in Finland. Innovation research in Finland is high quality, but funding has been difficult, and there has been too big gap for commercialization. (Yle 2016b) (Aino 2016).

Global connections and legalization of international ownership have increased the returns of forest industry. Increased pulp exports has been trend for the last decade, and trend seems to continue similar, which alarms for significant international lock-in. According to Figure 10, there can be internal path-dependency between the sources, e.g. education has affected R&D that has affected to P&P innovations that affects to bio-product innovations, and similarly, forest cluster has affected to global connections that has affected user-driven business in global level. This thesis considered lock-ins only in national level. Hence, this thesis calls further research to consider lock-in of the pulp industry in global scale. Concepts of path-dependency, lock-ins and TIC lowers costs, and naturally, new international lock-ins steers processing to countries where it is cheap as possible. In addition to Finland, pulp exports have increased also in Canada, where the value of pulp exports from Alberta and British Columbia to China, Taiwan and Hong Kong have increased from 600 million to 2250 million dollars in between 2000-2014 (Natural Resources Canada 2015).

The results were expected, and I believe that results would be quite similar in deeper analysis. While writing this thesis it has been difficult to generalize concepts of path-dependency and lock-in in the whole forest industry transition because every sector have had own transition. There are significant misses in the part of the transition, e.g. in the section related to policy. The most of material has been valid, and used less scientific material, e.g. media, has not affected to the results significantly. The material used in results is presented in Table 2.

Table 2: Used material in the results

Themes	Material type	Authors
Path-dependency	Scientific articles	Zhang et all, Kröger & Rautio, Kotilainen & Rytteri
	Literature	Kuisma et all, Leppälä, Seppälä, Laurila et all, Ahvenainen, Hilden et all, Lammi
	Research reports	VTT, Prime Minister’s Office, PTT
	Articles	Huuskonen et all, Huuskonen, Finnish Forest Industry, Hänninen
	Media	Klimaatti, Tekniikka & talous
	Other (discussion)	Niskanen et all
Lock-in	Scientific articles	Kotilaine & Rytteri
	Literature	Helander et all, Sierilä et all, Seppälä, Leppälä, Kuisma et all, Poutanen, Laurila et all,
	Articles	Metsähallitus, Finnish Forest Industries, SFS
TIC	Scientific articles	Kotilainen & Rytteri, Ranne
	Literature	Lammi, Leppälä, Helander, Sierilä, Seppälä, Kuisma et all
	Articles	Finnish Forest Industries, Huuskonen et all, Metsähallitus, VTT
	Media	Aino, Yle
	Other (presentation)	UPM

6 CONCLUSIONS

The multidimensional sources of increasing returns such as bio-product innovations, user-driven business, targets and certifications are identified in the Finnish forest industry. These sources have blurred the frameworks of dimensions of increasing returns by including primarily the elements of learning effects, adaptive expectations and network effects. The decreased added value of forest industry and market loss have forced companies to find alternative sources for increasing returns. So far, these multidimensional sources have exploited slightly despite of the identified potential.

Traditionally, the innovation search of forest industry has been path-dependent by lock-ins, which has occurred as bulk production, incremental process innovations and extended pulp-based products. Some of the companies have reacted in the early stage of current transition and seen the future via alternative bio-products, whereas some others have focused on improving the old products. The material of this thesis has conveyed how new products and transformation have seen as an opportunity or threat.

The forest industry have had implications of techno-institutional complex. The Finnish government used to have doer role in the forest industry by owning significant forest industry companies, practicing research work, accelerating forest modification, offering grants and loans and modifying legislation. The elements of forest industry TIC and the active role of government have benefit industries as well as citizens and the government, but parts of the benefit have lost. The actions towards higher added value, job creation and climate change mitigation have been low. Doers are needed.

7 SUMMARY

The Finnish government tackles climate change by bioeconomy that offers many ways to mitigation and at the same time, growth and jobs can be created (Kröger & Raitio 2017). (EBCD 2015). The Finnish forest industry is reforming (Finnish Forest Industries 2017a). The total added value of forest industry has decreased from 7 billion to 4 billion euros in between 2000-2016 (Luke 2016a). The product selection of the forest industry in the 2010s is based, and will most likely based on traditional products that added value is low (Prime Minister's Office 16/2017) (PTT 2017b). Pulp exports have almost tripled in between 2009-2018 (PTT2017c). This thesis is a first touch to Finnish forest industry from system transition point of view. The aim was to identify the returns of path-dependency, lock-in and TIC through production, product portfolio and organizations, and consider lock-in of innovation search in the case forest industry transition in Finland. Thesis focus on low value traditional wood products and high-value bio-products since 1850. Narrative analysis as a methodology allows using less scientific articles as a material.

The forest industry has faced challenges over the centuries, which have forced industry towards transition. Dominant sector has changed from tar-burning to sawmill industry to pulp industry, and nowadays the whole bio-product sector is in global transition due to changes related to technology, environment and society. (PTT 2017a). (Hetemäki 2009) The production has changed from dispersed hand-based home industry towards automated industrial plants (Leppälä 2012, 277,281) (Loukola 2001, 120). The product portfolio has diversified especially in the middle of the 20th century with paper and sawn good products, but also later in the 21st century with bio-products (Figure 7). The practices of organizations have adapted from agrarian society to independent nation with protectionism to modern globalized nation.

The results outlines how the multidimensional sources of increasing returns such as bio-products innovations, user-driven business, targets and certifications are identified in the forest industry in the 21st century. These sources of increasing returns have blurred the frameworks of dimensions by including primarily the elements of learning effects, adaptive expectations and network effects. Capacity to increase returns have varied between different sources of increasing returns. Institutional, technological and industrial lock-ins have primarily increased returns, but e.g. blocking competitors have also decreased available returns. Traditionally, the innovation search of forest industry has been path-dependent by lock-ins. Diversified product portfolio has been the sign of transformation of innovation search in the 21st century. The elements of TIC and the active role of government in TIC have increased returns. This thesis has reached the aim by identifying the returns of path-dependency, lock-in and TIC. The results were expected, and I believe that results would be quite similar in deeper analysis. While writing this thesis it has been difficult to generalize concepts of path-dependency and lock-in in the whole forest industry transition because every sector have had own transition. There are significant misses in the part of the transition, e.g. in the section related to policy.

Novothy & Laestadius (2014) studies concerning to P&P case in Sweden concluded how lock-in has varied between companies, and how transformation across the traditional framework has been possible. Their findings and this thesis support each other's. The multidimensional sources of increasing returns calls further research to consider, how these sources can be utilized in practical. Path-dependency of innovation search calls further research to consider how the innovation search can be improved and unlocked from the traditional forest industry framework for achieving more radical innovations. Increased returns by global connections, legalization of international ownership and pulp exports alarms for significant international lock-in, which calls further research to consider lock-in of the pulp industry in global scale.

The multidimensional sources of increasing returns such as bio-product innovations, user-driven business, targets and certifications have blurred the frameworks of dimensions of increasing returns by including primarily the elements of learning effects, adaptive expectations and network effects in the forest industry. The decreased value of forest industry products and market loss have forced companies to find alternative sources for increasing returns. So far, these multidimensional sources have been quite unexploited despite of the identified potential. Traditionally, the innovation search of forest industry has been path-dependent by lock-ins, which has occurred as extended pulp-based products, incremental process innovations, and hence bulk production. . The material of this thesis has conveyed how new products and transformation have seen as an opportunity or threat. The forest industry have had implications of techno-institutional complex. The Finnish government used to have doer role in the forest industry. The elements of forest industry TIC and the active role of government have benefit industries as well as citizens and the government, but parts of the benefit have lost. The actions towards higher added value, job creation and climate change mitigation have been low. Doer are needed.

REFERENCES

Ahvenainen Jorma. 1984. Suomen sahateollisuuden historia. Porvoo: WSOY. 461 pages. ISBN 951-0-12476-1.

Aino. 2016. Uudet innovaatiot pelastavat metsäteollisuuden. [Cited 11.7.2018]. Available: https://ainolehti.fi/aino/metsa-on-uusi-metsa/

Ammattinetti. 2018. Puutuoteteollisuus. [Cited 30.5.2018]. Available: http://www.ammattinetti.fi/ammattialat/detail/41_ammattiala?link=true

Arthur W.Brian. 1989. Competing Technologies, Increasing Returns and Lock-In by Historical Events. *The Economic Journal*, Vol. 99, No 394, pp. 116-131. Wiley on behalf of the Royal Economic Society.

Biotalous. 2015. Mäntyöljy on biopohjaisten tuotteiden aarreaitta. [Cited 15.4.2018]. Available:
http://www.biotalous.fi/mantyoljy-on-biopohjaisten-tuotteiden-aarreaitta/

Biotalous. 2017. Täysin hajoava Sulapac- materiaali haastaa muovin. [Cited 4.6.2018]. Available: http://www.biotalous.fi/taysin-biohajoava-sulapac-materiaali-haastaa-muovin/

Bioeconomy 2018. Wood and Forest. [Cited 12.7.2018]. Available http://www.bioeconomy.fi/wood-and-forest/

Chhetri Netra B et all. 2010. Modeling Path Dependence in Agricultural Adaptation to Climate Variability and Change. *Annals of the Association of American Geographers.*Volume 1000, 2010- Issue 4: Climate Change. Pages 894-907.

Cowan Robin. 1991. Tortoises and Hares: Choice Among Technologies of Unknown Merit. *The Economic Journal*, Vol. 101, No.407.

Cowan Robin, Bundy Philip. 1996. Sprayed to death: Path dependence, lock-in and pest control strategies. *The Economic Journal*, Vol. 106, No.436, pp.521.

David Paul. 1985. Clio and the Economics of QWERTY. *The American Economic Review*, Vol. 75, No. 2, pp. 332-337. American Economic Association.

EBCD. 2015. The role of bioeconomy in climate change mitigation. [Cited 15.4.2018]. Available: http://ebcd.org/the-role-of-bioeconomy-in-climate-change-mitigation/

Farmit. 2018. Mäntykuitu. [Cited 15.4.2018]. Available: https://www.farmit.net/metsa/puukauppa/metsasta-kayttajalle/puutavaralajit/mantykuitu

Fernandes Antonio S.C. 2012. Assessing the technology contribution to value added. *Technological Forecasting and Social Change.* Volume 79, Issue 2, February 2012, Pages 281-297.

Finnish Forest Association. 2016. Metsäenergia. [Cited 1.6.2018]. Available: https://www.smy.fi/forest-fi/metsatietopaketti/metsaenergia/

Finnish Forest Industries (Metsäteollisuus). 2007. Suomen metsäteollisuuden historia 1600-luvulta nykypäivään ainutlaatuisena kirjasarjana [Cited 7.6.2018]. Available: https://www.metsateollisuus.fi/tiedotteet/suomen-metsateollisuuden-historia-1600-luvulta-nykypaivaan-ainutlaatuisena-kirjasarjana/

Finnish Forest Industries (Metsäteollisuus). 2008. Tervasta Thermowoodin – puun vuosisadat. [Cited 9.4.2018]. Available: https://www.metsateollisuus.fi/tiedotteet/tervasta-thermowoodin-puun-vuosisadat/

Finnish Forest Industries (Metsäteollisuus). 2009.Innovaatio. [Cited 5.6.2018]. Available: https://www.metsateollisuus.fi/mediabank/579.pdf

Finnish Forest Industries (Metsäteollisuus). 2010. Paperi. [Cited 9.4.2018]. Available: https://www.metsateollisuus.fi/uploads/2017/03/30035322/475.pdf

Finnish Forest Industries (Metsäteollisuus). 2017a. Metsäteollisuuden tulevaisuuden toimintaympäristö. [Cited 27.7.2018]. Available: http://www.teollisuudenmetsanhoitajat.fi/wp-content/uploads/2017/08/Tomi-Salo-Tulevaisuus.pdf

Finnish Forest Industries (Metsäteollisuus). 2017b. Paperin tuotanto ja kulutus mailman markkinoilla. [Cited 6.6.2018]. Available: https://www.metsateollisuus.fi/edunvalvonta/tuotteet/paperin-tuotanto-kulutus-maailman-markkinoilla/

Finnish Forest Industries (Metsäteollisuus). 2018. Tilastot. [Cited 25.6.2018]. Available: https://www.metsateollisuus.fi/tilastot/

Finnish Government. 2018. Biotalous ja puhtaat ratkaisut. [Cited 5.6.2018]. Available: http://valtioneuvosto.fi/hallitusohjelman-toteutus/biotalous

Forest Cluster. 2016. Metsäklusterin strategianäkymät vuonna 2016. [Cited 17.4.2018]. Available: http://forestcluster.fi/metsaklusterin-strategianakymat-vuonna-2016/

Foxon Timothy. 2014. Technological Lock-in. *Encyclopedia of Energy, Natural Resource and Environmental Economics.* Volume 1, 2013, Pages 123-127.

Global shaper community. 2017. [Cited 17.7.2018]. Available: http://www.shaperssurvey2017.org/static/data/WEF_GSC_Annual_Survey_2017.pdf

Geels Frank. 2002. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case- study. *Research Policy.* Volume 31, Issues 8-9, December 2002, Pages 1257-1274.

Geels Frank. 2005. A socio-technical analysis of low-carbon transitions: introducing the multi-level perspective into transport studies. *Journal of Transport Geography.* Volume 24, September 2012, Pages 471-482.

Geels Frank. 2006. Co-evolutionary and multi-level dynamics in transitions: The transformation of aviation sytems and the shift from propeller to turbojet (1930-1970). *Technovation*. Volume 26, Issue 9, September 2006, Pages 999-1016.

Grabiola. 2011. Ksylitolin historia. [Cited 4.6.2018]. Available: http://graviola.fi/FI/kauppa-uutuudet/xylitol/Ksylitolin%20historia%20-%20Graviola.htm

Helander Benjamin. 1949. Suomen metsätalouden historia. WSOY. 546 pages.

Hetemäki Lauri, 2009. Metsäalan luova tuho. [Cited 20.6.2018]. Available: https://www.researchgate.net/profile/Lauri_Hetemaeki/publication/274640292_Metsaalan_luova_tuho/links/5524c9d40cf2b123c5175779/Metsaealan-luova-tuho.pdf

Helamo Markku. 2014. CLT-raakalevyn valmistus. [Cited 30.5.2018]. Available: http://www.kiintopuu.fi/media/kiintopuu/clt-raakalevy-info-4.4.14-pak.pdf

Helsingin sanomat. 2017. Tutkimus: Metsäteollisuudesta uhkaa tulla bulkin tuottaja- lähes joka kolmas työpaikka vaarassa [Cited 25.6.2018]. Available: https://www.hs.fi/talous/art-2000005087755.html

Hilden, Mikael et all. 2013. Uusi luonnonvaratalous.Helsinki: Gaudeamus. 302 pages. ISBN 978-952-495-285-9.

Hilden Mikael, Soimakallio Sampo. 2016. Kaikki biopolttoaineet eivät ole päästöttömiä. [Cited 5.6.2018]. Available: https://www.kauppalehti.fi/uutiset/kaikki-biopolttoaineet-eivat-ole-paastottomia/LLuVdNZR

Huuskonen Jouni et all. 2013. Yhteenveto innovaatioista sellu-, paperi- ja kartonkiteollisuudessa. [Cited 4.5.2018]. Available: https://www.puunjalostusinsinoorit.fi/site/assets/files/1356/innovaatioiden_yhteenveto_2014_painoversio.pdf

Huuskonen Jouni, Pakarinen Heikki. 2009. Paino- ja kirjoituspaperien kehitys 1970-90-luvuilla. [Cited 18.4.2018]. Available: https://www.puunjalostusinsinoorit.fi/biometsateollisuus/innovaatiot/4-paperin-ja-kartongin-valmistus/4.1-paino-ja-kirjoituspaperien-kehitys-1970-90-luvuilla/

Häggblom Rainer. 2014. Bulkkituotanto kannattaa. [Cited 15.6.2018]. Available: https://www.maaseuduntulevaisuus.fi/politiikka-ja-talous/bulkkituotanto-kannattaa-1.74435

Hämeen sanomat. 2018. Metsäteollisuus kävi kovan koulun. [Cited 12.7.2018]. Available: https://www.hameensanomat.fi/kolumnit/345521-metsateollisuus-kavi-kovan-koulun

Hämäläinen Sari, Näyhä Annukka, Pesonen Hanna-Leena. 2011. Forest biorefineries – A business opportunity for the Finnish forest cluster. *Journal of Cleaner Production.* Vol.19, N.16, pp 1884-1891.

Hänninen Riitta. 2013. Suomen metsäsektori monipuolistuu ja uudistuu. [Cited 12.7.2018]. Available:http://www.metla.fi/ohjelma/mtu/pdf/Suomen_metsasektori_monipuolistuu_ja_uudistuu_Hanninen_R.pdf

Häyrinen Eero. 2011. Thesis. University of Eastern Finland. [Cited 2.6.2018]. Available: http://epublications.uef.fi/pub/urn_nbn_fi_uef-20110128/urn_nbn_fi_uef-20110128.pdf

Ignatius Jorma. 2007. Yli 50 vuotta nestepaukkauskartonkia Imatralla. [Cited 22.4.2018]. Available: https://www.puunjalostusinsinoorit.fi/biometsateollisuus/innovaatiot/4-paperin-ja-kartongin-valmistus/4.12-nestepakkauskartonki/

Ilmastopaneeli. 2015. Metsien hyödyntämisen ilmastovaikutukset ja hiilinielujen kehittyminen. [Cited 31.7.2018]. Available: http://www.ilmastopaneeli.fi/uploads/selvitykset_lausunnot/Metsien%20hy%C3%B6dynt%C3%A4misen%20ilmastovaikutukset%20ja%20hiilinielujen%20kehittyminen.pdf

Isotalo Ilmo. 2011. Sähkötekniset erikoissellulaadut. [Cited 7.5.2018]. Available: https://www.puunjalostusinsinoorit.fi/biometsateollisuus/innovaatiot/2-sellun-valmistus/2.6-sahkotekniset-erikoissellulaadut/

Kaleva. 2004. Tervan tuotanto. [Cited 9.4.2018]. Available: http://www.kaleva.fi/terva/tervan-tuotanto/historiaa/544666/

Karhu Heikki. 2007. Painopaperi- ja kartonkilajit Suomessa. [Cited 1.5.2018]. Available: https://www.theseus.fi/bitstream/handle/10024/9446/Karhu.Heikki.pdf?sequence=2&isAllowed=y

Kauppalehti. 2015. Kaikki biopolttoaineet eivät ole päästöttömiä. [Cited 5.6.2018]. Available: https://www.kauppalehti.fi/uutiset/kaikki-biopolttoaineet-eivat-ole-paastottomia/LLuVdNZR

Kauppalehti. 2018. PTT ennustaa: metsäteollisuuden vienti jatkaa kasvua- lisääntyvä tuotanto vetää sellun hinnan laskuun. [Cited 5.6.2018]. Available: https://www.tekniikkatalous.fi/tekniikka/metsa/ptt-ennustaa-metsateollisuuden-vienti-jatkaa-kasvua-lisaantyva-tuotanto-vetaa-sellun-hinnan-lievaan-laskuun-6719687

Kekäläinen Reetta. 2015. CLT-rakentaminen. Thesis. Vaasa University of Applied Sciences [Cited 30.5.2018]. Available: https://www.theseus.fi/bitstream/handle/10024/87366/Kekalainen_Reeta.pdf?sequence=1

Kotilainen Juha, Rytteri Teijo. 2011. Transformation of forest policy regimes in Finland since the 19th century. *Journal of Historical Geography.* Vol 37, Nro.4, pp 429-439.

Korhonen Jaana. 2016. On the high to future forest sector competitiveness. Academic Dissertation. University of Helsinki. Available: https://helda.helsinki.fi/bitstream/handle/10138/161310/Onthehig.pdf?sequence=1

Kröger Markus, Raitio Kaisa. 2017. Finnish forest policy in the era of bioeconomy: A pathway to sustainability?. *Forest Policy and Economics.* Vol. 77, April 2017, pp 6-15.

Kuisma Markku. 2009. Suomen poliittinen taloushistoria 1000-2000. Helsinki: Siltala. 240 pages. ISBN 9789522340047.

Kuisma et all. 2014. Paperin painajainen. Helsinki: Juva: Bookwell Oy. 294 pages. ISBN 978-952-234-211-9.

Kujanpää Elisa. 2011. Terva, historia, valmistus käyttö. Thesis. Seinäjoki University of Applied Sciences [Cited 15.4.2018]. Available: http://www.theseus.fi/bitstream/handle/10024/36168/Kujanpaa_Elisa.pdf?sequence=1&isAllowed=y

Kunnas Jan. 2007. Potash, saltpeter and tar: Production, exports and use of wood in Finland in the 19th century. *Scandinavian Journal of History.* Vol. 32, Nro.3, pp. 281-311.

Könnölä Totti, Gregory C. Unruh, Carrillo-Hermosilla Javier. 2006. Prospective voluntary agreements for escaping techno-instiutional lock-in. *Ecological Economics.*Vol. 57, Nro. 2, pp. 239-252.

Könnölä Totti et all. 2007. Toward prospective voluntary afreements: reflections from a hydrogen foresight project. *Journal of Cleaner Production.* Volume 15, Issue 3, 2007, Pages 259-265.

Laborde Sarah et all. 2016. Social-ecological feedbacks lead to unsustainable lock-in in an inland fishery. *Global Environmental Change*. Volume 41, November 2016, Pages 13-25.

Laitinen Eero, Alakärppä, Reijo. 1995. Teollinen puurakentaminen. Helsinki: Rakennustieto Oy. 176 pages. ISBN 951-682-329-7.

Laitinen Markus. 2008. Puun modifiointimenetelmät. . [Cited 30.4.2018]. Available: https://www.theseus.fi/bitstream/handle/10024/11742/2008-04-30-02.pdf?sequence=1

Lammi Markku. 2000. Suomen metsäklusteri tienhaarassa. Vammala: Vammalan Kirjapaino Oy. ISBN 952-457-020-3

Laurila Juha, Mäkinen Eino, Vuorimaa Heikki. 1968. Metsäteollisuus itsenäisessä Suomeesa: Suomen puunjalostusteollisuuden keskusliitto 1918-1968. Helsinki: Frenckellin Kirjapaino Oy. 207 pages.

Leikola Matti. 2009. Metsähallitus valtion metsien hoitajana ja käyttäjänä 1859-2009. [Cited 15.5.2018]. Available: https://www.metsatieteenaikakauskirja.fi/pdf/article6769.pdf

Leppälä 2012 ???
Levonen Jussi. 2016. DigiPuu-seminaari. [Cited 1.6.2018]. Available: http://www.win-hanke.fi/images/LVL_esitys_Jussi_Levonen_DigiPuu-seminaari_Savonia-amk_28.4.2016.pdf

Liebowitz S.J, Margolis Stephen. 1995. Path-dependence, Lock-in and History. *Journal of Law, Economics & Organization*. Vol. 11, No. 1, pp. 205-226.

Loorbach Derk. 2010. Transition Management for Sustainable Development: A Prescriptive, Complecity- Based Governance Framework. *Governance* 23:1, 161-183.

Loukola Sakari. 2001. Puusta pitkään. Jyväskylä: Gummerrus Kirjapaino Oy. ISBN 951-0-25087-2

Luke. 2016a. Metsäteollisuuden tuotannon bruttoarvo ja jalostusarvo. [Cited 25.6.2018]. Available:http://statdb.luke.fi/PXWeb/pxweb/fi/LUKE/LUKE__04%20Metsa__08%20Muut__Metsateollisuus/10.05_Metsateollisuuden_tuotannon_bruttoarvo_ja.px/?rxid=001bc7da-70f4-47c4-a6c2-c9100d8b50db

Luke. 2017a. Metsäteollisuuden puunkäyttö 2016. [Cited 6.4.2018]. Available: http://stat.luke.fi/metsateollisuuden-puun-kaytto

Luke. 2017b. Kotimaisen raakapuun käyttö nousi ennätystasolle 2017. [Cited 19.6.2018]. Available: https://www.luke.fi/uutiset/kotimaisen-raakapuun-kaytto-nousi-ennatystasolle-2017/

Luke. 2018a. Metsät ja ilmasto. [Cited 17.7.2018]. Available: https://www.luke.fi/tietoa-luonnonvaroista/metsa/metsat-ja-ilmastonmuutos/

Luke. 2018b. Tilastotietokanta. [Cited 12.7.2018]. Available: http://statdb.luke.fi/PXWeb/pxweb/fi/LUKE/LUKE__04%20Metsa__08%20Muut__Metsateollisuus/?tablelist=true&rxid=37351054-dec1-4d3a-9964-7e4fad7f285c

Luukkonen Jesse. 2017. Teollisen puurakentamisen edistäminen Suomessa. [Cited 23.4.2018]. Available: https://www.theseus.fi/bitstream/handle/10024/121996/Luukkonen_Jesse_2017_02_01.pdf?sequence=1&isAllowed=y

Maaseudun tulevaisuus. 2017a. Metsäteollisuus rikkoi ennätyksiä huippusuhdanteessa. [Cited 27.7.2018]. Available: https://www.maaseuduntulevaisuus.fi/mets%C3%A4/artikkeli-1.218810

Maaseudun tulevaisuus. 2017b. Maaperän hiilivarastoilla on väliä Pariisin ilmastosopimuksen kaudella. [Cited 20.7.2018]. Available: https://www.maaseuduntulevaisuus.fi/puheenaiheet/vieraskolumnit/maaper%C3%A4n-hiilivarastoilla-on-v%C3%A4li%C3%A4-pariisin-ilmastosopimuksen-kaudella-1.201133

Maaseudun tulevaisuus. 2018. Ministeri Tiilikainen: Lukuisat metsäteollisuuden investointisuunnitelmat eivät hirvitä. [Cited 20.7.2018]. Available:https://www.maaseuduntulevaisuus.fi/mets%C3%A4/artikkeli-1.234630

Martikainen Kati. 2017. Thesis. Metropolia University of Applied Sciences [Cited 1.6.2018]. Available: https://www.theseus.fi/bitstream/handle/10024/139682/Martikainen_Kati.pdf?sequence=1

Meadowcroft James. 2006. Environmental political economy, technological transitions and the state. *New Political Economy.* Vol. 10 No. 4, pp. 479-98.

Metla. 2010. Suomalaisten itsenäisten sahojen tuotannon tehokkuus 2000-luvulla. [Cited 5.6.2018]. Available: http://www.metla.fi/julkaisut/workingpapers/2010/mwp167.pdf
Metsähallitus. 2015. Metsähallituksen 150-vuotinen historia lyhyesti. [Cited 23.7.2018]. Available: http://www.metsa.fi/150vuottalyhyesti

Metsäyhdistys. 2015. Metsäpolitiikka. [Cited 16.5.2018]. Available: https://www.smy.fi/forest-fi/metsatietopaketti/metsapolitiikkaa-jo-1800-luvulta/

Metsäteollisuus ry & Paperiliitto ry. 2006. Paperiteollisuus-Toimialan tilanne ja tulevaisuuden haasteet. [Cited 30.7.2018]. Available: https://www.tsr.fi/documents/20181/40645/107240-Paperiteollisuus_loppuraportti_31-05-2006FINAL.pdf/d6657a51-995f-4a99-a2dc-1092fd3b69b5

METSÄ Group. 2017. Tilinpäätös. [Cited 29.8.2018]. Available: https://www.metsagroup.com/en/Documents/Publications/Metsa-Group-tilinpaatos-2017.pdf

Ministry of Agriculture and Forestry. 2018. [Cited 5.6.2018]. Available: http://mmm.fi/metsat/puun-kaytto/liikenteen-biopolttoaineet

MTK. 2016. Katsaus metsäsertifiointiin pintaa syvemmältä. [Cited 27.6.2018]. Available: https://www.mtk.fi/ajankohtaista/blogit/euroopan_ytimesta/katsaus_metsasertifiointiin/fi_FI/katsaus_metsasertifiointiin_pintaa_syvemmalta/

National Board of Waters. 1985. Selvitys saha- ja kyllästystoiminna sekä uiton ja tukkien vesiensuojelukysymyksitä. [Cited 25.5.2018]. Available:https://helda.helsinki.fi/bitstream/handle/10138/153404/Vesihallitus%20Tiedotus%20258.pdf?sequence=1

National Resources Canada. 2015. East and Werst – a shift of the historical distribution and dynamixs of Canadian pulp production. [Cited 5.9.2018]. Available:https://cfs.nrcan.gc.ca/selective-cuttings/87

Niemi Tuomo. 2013a. Oulun mäntyöljy- ja tärpättijalosteet. [Cited 30.4.2018]. Available: https://www.puunjalostusinsinoorit.fi/en/bioforest-industry/innovaatiot/9-sivutuotteet-ja-selluloosan-jatkojalosteet/9.9-oulun-mantyoljy-ja-tarpattijalosteet/

Niemi Tuomo. 2013b. Johdanto selluteollisuuden kehitykseen. [Cited 28.5.2018]. Available: https://www.puunjalostusinsinoorit.fi/biometsateollisuus/innovaatiot/2-sellun-valmistus/2.1-johdanto-selluteollisuuden-kehitykseen/

Niinikoski Eero. 2010. Jokapäiväinen paperimme.[Cited 1.6.2018]. Available: http://www.craftmuseum.fi/kiertonayttelyt/jokapaivainen_paperimme/jokapaivainen_paperimme_kasiohjelma.pdf

Niskanen Anssi, Absetz Ilmari, Kuuramaa Ilkka. 2003. Elinkeinot globaalimuutosten pyörteissä. [Cited 29.8.2018]. Available: http://www.metsafoorumi.fi/dokumentit/sem1_julk.pdf

Novotny Michael & Laestadius Staffan. 2014. Beyond papermaking: technology and market shifts for wood-based biomass industries- management implications for large-scale industries. *Technology Analysis & Strategic Management.* Pages 875-891.

Näsi Risto. 2010. Mäntyöljy biodieselin raaka-aineena. [Cited 1.6.2018]. Available: https://www.forchem.com/files/389/mantyoljyn-kaytto-biodiesel-raaka-aineena.pdf

Oberling Daniel Fontana. 2012. Investments of oil majors in liquid biofuels: The role of diversification, integration and technological lock-ins. *Biomass and Bioenergy*. Volume 46, November 2012, Pages 270- 281.

Paaskoski Leena, Virtanen Pekka. 1995. Metsää etsimässä. Punkaharju: Lusto. ISBN 951-97272-0-5.

Perkins Richard. 2003. Technological ”lock-in”. International *Society for Ecological Economics.*

Pierson Paul. 2000. Increasing Returns, Path Dependence, and the Study of Politics. *The American Political Science Review.*Vol.93, No.2. pp. 251-267

Pohjakallio Maija. 2015. Mäntyöljy on biopohjaisten tuotteiden aarreaitta. [Cited 1.6.2018]. Available: http://www.biotalous.fi/mantyoljy-on-biopohjaisten-tuotteiden-aarreaitta/

Poutanen Tuomo. 2000. Suomen metsäklusteri tienhaarassa. Vammala: Vammalan Kirjapaino Oy. ISBN 952-457-020-3

Puuinfo. 2001. Puutuotteet hiilivarastoina. [Cited 30.7.2018]. Available: https://www.puuinfo.fi/sites/default/files/Puutuotteiden%20hiilen%20kierto%20a4.pdf

Puuinfo. 2018. CLT by Stora Enso (Cross-laminated timber). [Cited 30.5.2018]. Available: https://www.puuinfo.fi/tuote/clt-stora-enso-cross-laminated-timber

Puuntuottaja 2014. Kiintokuutiosta puuta tulee 113 eurolla sellua. [Cited 19.6.2018]. Available: http://www.puuntuottaja.com/kiintokuutiosta-puuta-tulee-113-eurolla-sellua/

Prime Ministers Office 16/2017. 2017. Towards bioeconomy: barriers and redirection of regulation. [Cited 31.7.2018]. Available: http://julkaisut.valtioneuvosto.fi/handle/10024/160323

PTT. 2017a. Tiedote: Teollisuuden tuotos kasvaa puun käyttöä hitaammin- biotalouden tavoitteita ei saavuteta ilman tutkimusta ja uusia tavoitteita. [Cited 30.5.2018]. Available: http://www.ptt.fi/julkaisut-ja-hankkeet/kansantalouden-tutkimusryhma/tiedote-teollisuuden-tuotos-kasvaa-puun-kayttoa-hitaammin-biotalouden-tavoitteita-ei-saavuteta-ilman-tutkimusta-ja-uusia-tuotteita.html?tagged=Mets%C3%A4sektori

PTT. 2017b. Kasvava metsäteollisuuden vienti nostaa metsänomistajien tuloja. [Cited 19.6.2018]. Available: http://www.ptt.fi/ennusteet/metsaala/metsasektori-2017-syksy.html

PTT. 2017c. Uudet investoinnit ja sahateollisuuden kohentuneet markkinanäkymät suuntaavat metsäsektorin kehitystä. [Cited 25.6.2018]. Available:http://www.ptt.fi/ennusteet/metsaala/metsasektori-2017-kevat.html

Rautiainen Miina. 2017. Sellua löytyy kohta mitä ihmeellisimmistä paikoista- “ Se on terästä kovempaa tavaraa”. [Cited 1.6.2018]. Available: https://www.tekniikkatalous.fi/tiede/tutkimus/sellua-loytyy-kohta-mita-ihmeellisemmista-paikoista-se-on-terasta-kovempaa-tavaraa-6688009

Riessman, Catherine Kohler (2005) Narrative Analysis. In: Narrative, Memory & Everyday life. University of Huddersfield, pp. 1-7.

Romppanen Seita. 2018. Kierto- ja biotalouden oikeudellinen sääntely- uhka vai mahdollisuus? [Cited 28.7.2018]. Available: http://www.uef.fi/documents/371347/1933270/seitar_ESITYS_uusi.pdf/62e6b4d1-5fa6-4592-afd6-bcbe6e10d3ed

Rotmans Jan, Loorbach Derk. 2009. Complexity and Transition Management. *Journal of Industrial Ecology*. Vol. 13, Nro.2, pp. 184-196.

Sathre Roger, Gustavsson Leif. 2009. Process-Based Analysis of Added Value in Forest Product Industries. *Forest Policy and Economics*. Vol. 11, Nro. 1, pp. 65-75.

Sanditov Bulat. 2005. Patent Citations, the Value of Innovations and Path- Dependency.

Salste Matti. 2011. Nestepakkauskartonki. [Cited 20.4.2018]. Available: https://www.puunjalostusinsinoorit.fi/biometsateollisuus/innovaatiot/4-paperin-ja-kartongin-valmistus/4.12-nestepakkauskartonki/

Seppälä Heikki. 2013. FEFCO-9 liimaustestaus. [Cited 1.5.2018]. Available: https://www.theseus.fi/bitstream/handle/10024/58862/Heikki_Seppala.pdf?sequence=1&isAllowed=y

Seppälä Risto. 2000. Suomen metsäklusteri tienhaarassa. Vammala: Vammalan Kirjapaino Oy. ISBN 952-457-020-3
SFS. 2017. A4 90 vuotta Suomessa. [Cited 15.6.2018]. Available: https://www.sfs.fi/ajankohtaista/uutiset/a4_90_vuotta_suomessa.4475.news

Sierilä Pentti, Suomalainen metsäteollisuus: kukoistava menneisyys, mahdollisuuksien tulevaisuus; teollisuustaloudellinen kuvaus metsätaloudesta pähkinänkuoressa 2011

Sinclair Penny, Walton Julia. 2003. Environmental Reporting Within the Forest and Paper Industry. *Business Strategy and the Environment.* Vol. 12, pp. 326-337.

Sitra. 2018. Mitä nämä käsitteet tarkoittavat? [Cited 11.7.2018]. Available: https://www.sitra.fi/artikkelit/mita-nama-kasitteet-tarkoittavat/

Smith, Charles P. "Content analysis and narrative analysis." Handbook of research methods in social and personality psychology (2000): 313-335.

Sondeijker Saartje et all. 2006. Imagining sustainability: the added value of transition scenarios in transition management. *Foresight.* Vol. 8 Issue: 5, pp. 15-20.

STAT. 2007. Energian käyttö ja lähteet 1917-2007. [Cited 19.7.2018]. Available: https://www.stat.fi/tup/suomi90/maaliskuu.html

STAT 2018. Tuotannon jalostusarvo. [Cited 25.6.2018]. Available: http://www.stat.fi/meta/kas/jaleu.html

Stora Enso. 2017. Progress book. [Cited 16.6.2018]. Available: http://assets.storaenso.com/se/com/DownloadCenterDocuments/STORAENSO_Progress_2017_FIN.pdf

Stora Enso 2018. Ligniini on tulevaisuutta. [Cited 19.7.2018]. Available: http://www.storaenso.com/lang/finland/about/Pages/Ligniini-on-tulevaisuutta.aspx

Suomen kuvalehti. 2008. Metsäteollisuus hölmöili itsensä kriisiin. [Cited 12.7.2018]. Available: https://suomenkuvalehti.fi/jutut/kotimaa/talous/metsateollisuus-holmoili-itsensa-kriisiin/

Tekniikka & talous. 2012. Metsäklusteri Oy muuttuu biotalouteen erikoistuvaksi FIBIC:iksi. [Cited 15.6.2018]. Available: https://www.tekniikkatalous.fi/tekniikka/metsa/2012-08-21/Mets%C3%A4klusteri-Oy-muuttuu-biotalouteen-erikoistuvaksi-FIBICiksi-3310255.html

Tekniikka & talous. 2014. Metsäteollisuus ennen, nyt ja tulevaisuudessa. [Cited 27.7.2018]. Available:https://www.tekniikkatalous.fi/kumppaniblogit/ey/2014-06-02/Mets%C3%A4teollisuus-ennen-nyt-ja-tulevaisuudessa-3319965.html

Tekniikka & talous. 2017. EU lopettaa typerän kaksoislaskennan sekoitusvelvoiteesta voi tulla seuraava byrokratiapaikku. [Cited 6.6.2018]. Available: https://www.tekniikkatalous.fi/puheenvuorot/eu-lopettaa-typeran-kaksoislaskennan-sekoitusvelvoitteesta-voi-tulla-seuraava-byrokratiapaukku-6617876

Tekniikka & talous. 2018. Katso täältä suorana, löytyykö näistä innovaatioista metsäteollisuuden uusi maailmanvalloittaja. [Cited 25.6.2018]. Available: https://www.tekniikkatalous.fi/tekniikka/metsa/katso-taalta-suorana-loytyyko-naista-innovaatioista-metsateollisuuden-uusi-maailmanvalloittaja-lahetys-kello-11-35-13-00-6727498

Tekes. 2004. Value Added Wood Chain. Sipoo: Paino Center. ISBN 1239-1336

Thermowood. 2017. International Thermowood association. [Cited 1.5.2018]. Available: https://www.thermowood.fi/1

Tulevaisuusvaliokunta. 2013. Kaikkea muuta puusta. [Cited 1.6.2018]. Available: https://www.eduskunta.fi/FI/tietoaeduskunnasta/julkaisut/Documents/tuvj_3+2013.pdf

Tuominen Miika. 2011. Moderni sahatekniikka. Thesis. Lahti University of Applied Sciences. [Cited 30.5.2018]. Available: http://www.theseus.fi/bitstream/handle/10024/32502/Tuominen_Miika.pdf?sequence=2

Unruh Gregory. 2000. Understanding carbon lock-in. *Energy Policy*. Volume 28, Issue 12, 1 October 2000, Pages 817-830.

Unruh Gregory. 2002. Escaping carbon lock-in. *Energy policy*.

UPM. 2008. UPM- näkökulma metsäteollisuuden tulevaisuuteen. [Cited 15.6.2018]. Available:http://docplayer.fi/1075175-Upm-nakokulma-metsateollisuuden-tulevaisuuteen-toimitusjohtaja-jussi-pesonen-upm.html

UPM. 2013. Tulevaisuuden biopolttoaine valmistetaan puusta. [Cited 16.4.2018]. Available:
https://frantic.s3.amazonaws.com/smy/2014/10/PMA35_Jaakko-Nousiainen_diat.pdf

Vahala Eero. 2016. Hirsitalo asuinrakennuksen vaihtoehtona. [Cited 2.5.2018]. Available: https://www.theseus.fi/bitstream/handle/10024/107219/Vahala_Eero.pdf?sequence=2&isAllowed=y

Vanninen Markus. 2009. Tyypillisten biomassamateriaalien kemiallinen koostumus. Thesis University of Jyväskylä.
https://jyx.jyu.fi/bitstream/handle/123456789/21265/URN_NBN_fi_jyu-200906261753.pdf?sequen

Vesanen Tero, Viljakainen Mikko. 2014. Liimapuukäsikirja Osa 1. [Cited 24.4.2018]. Available: https://www.puuinfo.fi/sites/default/files/Liimapuu_low.pdf

Viitala Esa-Jussi. 2016. Liukosellun lupaus. . [Cited 1.6.2018]. Available: http://www.metla.fi/aikakauskirja/full/ff16/ff163181.pdf

VTT Technology 115. 2013. Carbon footprint for building products. [Cited 25.4.2018]. Available: http://www.vtt.fi/inf/pdf/technology/2013/T115.pdf

VTT Technology 126. 2013. Palvelukonseptien kehittäminen puutuoteteollisuudessa. [Cited 6.6.2018]. Available: https://www.hankeportaali.fi/assets/files/uploads/file-81.pdf

VTT Technology 199. 2014. Opas selluloosananomateriaaleihin. [Cited 26.6.2018]. Available: https://www.vtt.fi/inf/pdf/technology/2014/t199.pdf

VTT Technology 258. 2016. Suomessa käytettävien polttoaineiden ominaisuuksia. [Cited 20.6.2018]. Available: https://www.vtt.fi/inf/pdf/technology/2016/T258.pdf

VTT. 2006. Innovaatiojohtaminen ja sen vaikutuksia metsäteollisuudessa. [Cited 31.7.2018]. Available:https://www.vtt.fi/inf/pdf/publications/2006/P622.pdf

VTT. 2016a. Sopiiko elinkaariarviointi poliittisen päätöksenteon tueksi?. [Cited 31.7.2018]. Available: https://www.vtt.fi/Impulssi/Pages/Sopiiko-elinkaariarviointi-poliittisen-p%C3%A4%C3%A4t%C3%B6ksenteon-tueksi.aspx

VTT. 2016b. Puun komponentit parantamaan elintarvikkeiden laatua. [Cited 4.6.2018]. Available: https://www.vtt.fi/medialle/uutiset/puun-komponentit-parantamaan-elintarvikkeiden-laatua

VTT. 2017. Uudenlaista liiketoimintaa selluloosasta. [Cited 6.6.2018]. Available: https://www.vtt.fi/Impulssi/Pages/Uudenlaista-liiketoimintaa-selluloosasta.aspx

Wainstein Martin, Bumpus Adam. 2016. Business models as drivers of the low carbon power system transition: a multi-level perspective. *Journal of Cleaner Production.* Volume 126, 10 July 2016, Pages 572-585.

Yle. 2016a. Metsäteollisuuden rakennemuutos on kestänyt 12 vuotta- ”Tulosten paranemine on ollut kovan työn takana”. [Cited 30.7.2018]. Available: https://yle.fi/uutiset/3-8856370

Yle. 2016b. Öljyjätti ihmettelee, miksi suomalaiskeksintöä ei hyödynnetä Suomessa- Bioalan yritys lähellä läpimurtoa Intiassa. [Cited 4.6.2018]. Available: https://yle.fi/uutiset/3-8879890

Yle. 2017a. Nanosellu on tulevaisuuden supermateriaali – niin lujaa, että sitä on testattu luotiliivien materiaaliksi. [Cited 26.6.2018]. Available: https://yle.fi/uutiset/3-10198035

Yle. 2017b. Syöpälääkkeitä ja flunssarohtoja, tunnetko Suomen terveellisimmät puut?. [Cited 4.6.2018]. Available:https://yle.fi/uutiset/3-9391880

Yle. 2017c. ”Sinä päivänä autot lakkaavat ruostumasta”- Näillä aloilla knnattaisi tehdä innovaatioita. [Cited 30.7.2018]. Available: https://yle.fi/uutiset/3-9784035

Yle. 2018. Sellu ja lautatavara myy kuin häkä – metsäteollisuus rikkoio tuotantoennätyksiä halvemmilla tuotteilla. . [Cited 12.7.2018]. Available: https://yle.fi/uutiset/3-10069004

Zhang Yijing, Toppinen Anne, Uusivuori Jussi. 2014. Internationalization of the forest products industry: A synthesis of literature and implications for future research. *Forest Policy and Economics.* Vol. 38, pp. 8-16.

Äänekoski. 2018. Kartonkitehdas. [Cited 1.5.2018]. Available: http://www.arkistot.info/pukkimakea/kartonkitehdas.php