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Reporting of Green Supply Chain Management and Industrial Symbiosis

Master's Thesis

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ABSTRACT

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The purpose of this thesis is to examine how the reporting of operations related to green supply chain management and industrial symbiosis has evolved in UPM, Fortum and Kemira within the last ten years. The focus is on the improved operations, which are studied based on annual reports of these companies. The study provides a deeper understanding of the nature of green supply chain management and industrial symbiosis as well as the possibilites that their combination offers. The research is part of the DemaNET research project

The study indicates that the environmental regulations and reporting standards have forced the studied companies to report their operations related to green supply chain management and industrial symbiosis more in detail during the last ten years. The operations related to green supply chain management in the studied companies are more common compared to operations related to industrial symbiosis. Often these two operations were also partially integrated, indicating a hybrid model. Even though firms often used hybrid models they still focused mainly on greening the internal operations rather than finding alternative ways for symbiosis outside the organization. The integration of green supply chain management and industrial symbiosis is most likely to occur when mutually beneficial relationships align the interests of all parties, thus resulting in the co-creation of value. The findings suggest that identifying mutual benefits and the flow of by-products are the ones that companies should give more attention to.

TIIVISTELMÄ

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Tämän diplomityön tarkoituksena on tutkia miten raportointi liittyen vihreän toimitusketjun johtamiseen sekä teolliseen symbioosiin on muuttunut viimeisen kymmenen vuoden aikana UPM:llä, Fortumilla sekä Kemiralla. Työssä keskitytään yritysten kehittyneisiin toimintoihin, joita tutkitaan vuosiraporttien avulla. Tutkimus syventää ymmärrystä vihreän toimitusketjun johtamisesta ja teollisesta symbioosista, sekä niiden yhdistelmän tarjoamista mahdollisuuksista. Työ on osa DemaNET -tutkimusprojektia. Tutkimus osoittaa, että ympäristösäädökset sekä raportointikäytännöt ovat pakottaneet yritykset raportoimaan toiminnoistaan liittyen vihreän toimitusketjun johtamiseen sekä teolliseen symbioosiin yksityiskohtaisemmin vuosikymmenen saatossa. Vihreän toimitusketjun johtamiseen liittyvät toiminnot ovat tutkituissa yrityksissä yleisempiä verrattuna teolliseen symbioosiin. Usein nämä toiminnot esiintyivät myös osittain integroituneina, viitaten niin sanottuun hybridimalliin. Vaikka yritykset käyttivät tällaisia hybridimalleja, keskittyivät ne usein pääasiassa vain sisäisten toimintojen kehittämiseen ulkoisten toimintamahdollisuuksien löytämisen sijasta. Vihreän toimitusketjun johtamisen ja teollisen symbioosin yhdistelmä esiintyy todennäköisimmin silloin, kun kaikkien toimitusketjun toimijoiden ja sidosryhmien intressit kohtaavat, synnyttäen arvon yhteisluontia. Tutkimus osoittaa, että yhteisten hyötyjen tunnistaminen sekä sivutuotteiden hyödyntäminen toimitusketjuissa ovat alueita, joihin yritysten tulisi keskittyä.

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1. INTRODUCTION

It has become clear that our climate system is warming. According to the Intergovernmental Panel on Climate Change (IPCC), carbon dioxide concentrations have increased by 40% since pre-industrial times. However, only since the 1950s, the warming of the climate system has been unequivocal because there have been more comprehensive and diverse sets of observations available. These observations have proven that the atmosphere and the ocean have warmed, the amounts of snow and ice have diminished, the sea level has risen and the concentrations of greenhouse gases have increased. Therefore, continued emissions of these greenhouse gasses will cause further warming and changes in all components of the climate system. In fact most aspects of the climate change will persist for many centuries even if CO_2 emissions are stopped, and thus substantial and sustained ways to reduce greenhouse gas emissions will be required to limit this change. (IPCC 2013)

Green supply chain management (GSCM) and industrial symbiosis (IS) are both sustainable ways to reduce emissions and wastes, and thus researched in this thesis. Both of these concepts are also quite new subjects in reserch, which adds value to this thesis. In supply chain research the aim is to reduce waste within a firm whereas in industrial symbiosis the aim is to reduce waste over the entire system of firms. This basically means that in industrial symbiosis waste is thought as a fuel and opportunities extend beyond pollution control. (Bansal & McKnight 2009)

The literature review of this thesis focuses on the possibilities of green supply chain management and industrial symbiosis. It also aims to shed light on the challenges and how to overcome these challenges to implement these techniques. The empirical part is focused on the review of annual reports between 2004 and 2013 of three large Finnish industrial companies. These annual reports are coded based on the operations in green supply chain management and industrial symbiosis. The research reveals how the operations have improved during the time frame and aims to conclude what could be learned from these operations to limit the climate change in the future.

1.1 Background of the study

This master's thesis is a part of the DemaNET research project that is funded by the Green Growth programme within the Finnish Funding Agency for Technology and Innovation (TEKES). This project is carried out in collaboration with Lappeenranta University of Technology. The Finnish industrial companies researched in this thesis are UPM, Fortum and Kemira, which are all part of the DemaNET project. The research is an analysis of annual reporting of these companies and operations regarding green supply chain management and industrial symbiosis. The aim is to provide empirical data of operations and study their improvement by using structured content analysis.

1.2 Objectives and research questions

The purpose of this thesis is to examine how the reporting of operations related to green supply chain management and industrial symbiosis has evolved in UPM, Fortum and Kemira within the last ten years. The focus is on the improved operations, which are studied based on annual reports. The theoretical ground for this research is built by studying the existing literature in the fields of green supply chain management and industrial symbiosis. The findings related to causality of these concecpts are valuable, because the connection between industrial symbiosis and green supply chain management has not been studied much. Based on the literature, I will review how the operations in GSCM and IS have improved in the chosen companies and the aim is to create a more complete understanding of these concepts and how to implement them more effectively in the future. The research questions are exhibited in table 1 and are based on the coding of annual reports.

Table 1. Research questions

How have the reported operations related to green supply chain management improved in chosen industrial firms within the last ten years?
How have the reported operations related to industrial symbiosis improved in chosen industrial firms within the last ten years?
What possibilities could the combination of green supply chain management and industrial symbiosis offer?

The first two research questions aim to conclude how the operations related to GSCM and IS have improved in the chosen industrial firms within the last ten years based on annual reports. Because the coding is based on annual reports I will also analyze the reporting of the operations. The third research question is a result of analyzing the operations related to GSCM and IS in chosen industrial companies and concluding what possibilites could the combination of these two methods bring forth.

The environmental management is a broad concept encompassing all efforts to minimize negative environmental impact of organizations' operations, and is therefore too broad to study as whole in this research. Thus, risk management inside organisations own operations will be excluded from this research.

1.3 Structure of the study

This chapter describes the research process and the structure of this study. The structure including inputs and outputs is presented in the figure 1. Also a brief overview of each chapter is presented.

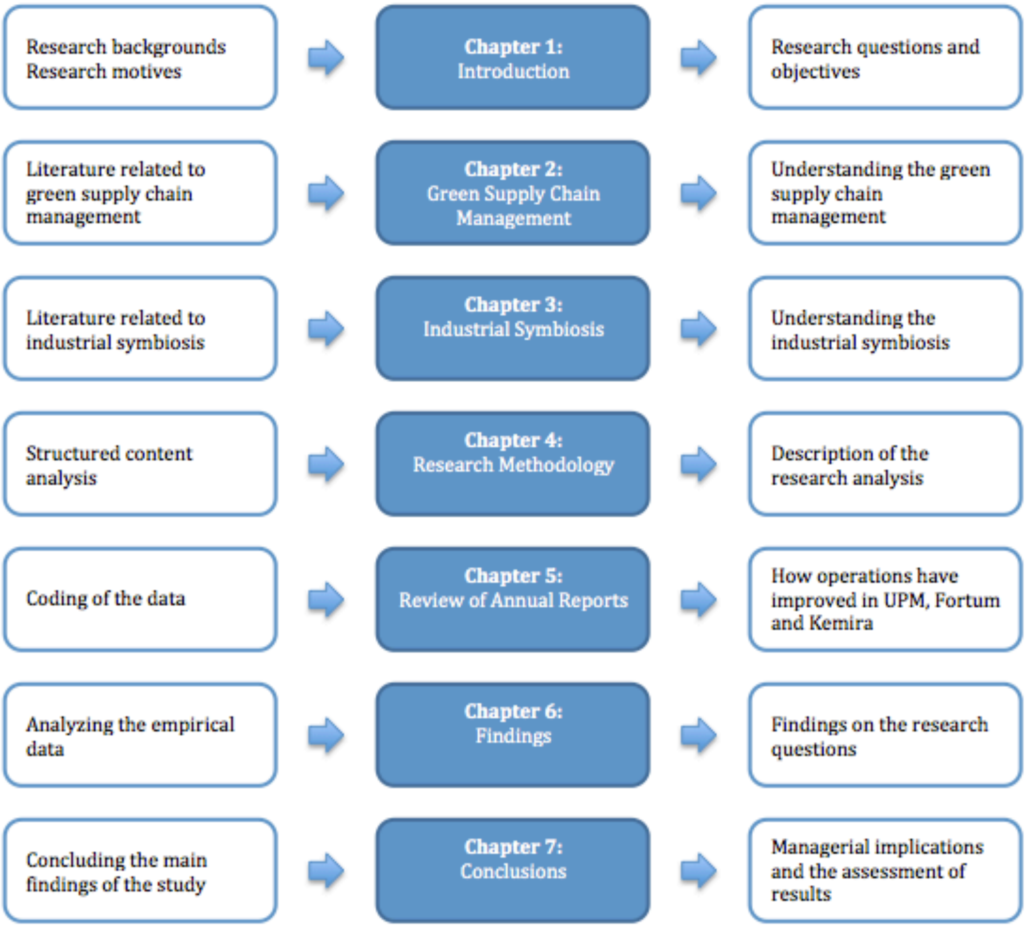

Figure 1. Structure of the thesis

Chapter one consists of the introduction of the study where I have explained the importance of green supply chain management and industrial symbiosis in reducing greenhouse gas emissions. In addition the reason why I have chosen to analyze annual reports of UPM, Fortum and Kemira is explained, in addition to the objectives and research questions.

Chapter two and three provide the theoretical background for this study by explaining the concepts of green supply chain management and industrial symbiosis. The relationship of GSCM and IS is also discussed because it offers possibilites that are later analyzed in the annual reports. Also the challenges and how to overcome those are presented including a short overview of literature and why it is important to analyze just annual reports before moving on to methodology part.

Chapter four explains what is structured content analysis and why it is used as the research methodology for this thesis. I have also presented the process of data collecting and analyzing.

In chapter five the annual reports of UPM, Fortum and Kemira are coded with structured content analysis based on their operations in green supply chain management and industrial symbiosis. The imporevement of these operations can be seen from this chapter.

In chapter six I answer the research questions based on the analysis of annual reports and analyse findings. Finally I conclude this thesis with the answers to research questions including managerial implications and delimitations of the research.

2. GREEN SUPPLY CHAIN MANAGEMENT

Green supply chain management has its roots in both supply chain management and environmental management literature. Generally the "green" component refers to the relationship and influence between supply-chain management and the natural environment. (Srivastava 2007) The fundamentals of greening are explained by Porter and van der Linde (1995) and their idea was that investments in greening could be resource saving, productivity improving and waste eliminating.

In a supply chain customers and stakeholders do not always distinguish the difference between a company and its suppliers (Rao 2005). The reason is that processes of production are often spread around the globe where suppliers, focal companies and customers are linked by flows of materia, capita and information. With the value of the product comes the environmental and social burden incurred during various stages of production. Because of this focal companies of supply chains are mostly held responsible for the environmental and social performance of their suppliers. (Seuring & Müller 2008)

Handfield and Nichols (1999) define supply chain management as all the activities associated with the flow and transformation of materials from raw extraction phase through to the consumption of goods and services by the end user, as well as the information flows, both up and down the supply chain. This was a new way of thinking because before the end of the 90's most scientific articles were exploring environmental initiatives only within each of the major phases of the supply chain. However in the research of green supply chain management it is necessary to focus on the totality of the supply chain in both upstream and downstream directions (Rao 2005).

The escalating deterioration of the environment is why companies have a growing need for integrating environmentally sustainable choices into supply-chain management (Srivastava 2007). Generally it is perceived that green supply chain management creates efficiency and synergy among networks, enhances environmental performance, minimizes wastes and saves costs. At the same time it is expected to enhance corporate image and create competitive advantage so it is also about good business sense and higher profits. (Rao 2005) Thus organizations will only adopt green supply management practices if they identify financial and operational benefits (Bowen et al. 2001).

2.1 Definitions and terminology of GSCM

For many organizations green supply chain management is a way to demonstrate commitment to sustainability (Bacallan, 2000). Sustainable development is defined as "a development that meets the need of the present without compromising the ability of future generations to their own needs" (WCED 1987).

The definition of green supply chain, which could range from reactive monitoring of general environmental management programs to more proactive practices such as remanufacturing and recycling of environmental management differs quite a lot. This disagreement of the definition of green supply chain management is not surprising since it links the elements of corporate environmental management and supply chain management which are both relatively new areas of study and practice. (Sarkis 2004)

This has lead to integration of environmental concerns in supply chain management and has evolved into a separate and growing field with hundreds of academic papers during the past couple decades. Also some relevant literature reviews have been made such as Seuring & Müller (2008), Srivastava (2007) and Sarkis (2012).

Before the definitions of green supply chain management in table 3, it is essential to examine some terminology for the concept of green supply chain management that has had many variations. Within operations and supply chain management fields these include for example journals related to GSCM topics that have been defined as sustainable supply chains as seen in table 2.

Table 2. Terminology of GSCM in academic journals

Environmental supply chain management (Zsidisin & Sifred 2001)
Environmental logistics (Gonzàlez-Benito 2006)
Green logistics (Murphy & Poist 2000)
Green supply (Bowen et al. 2001)
Supply chain environmental management (Lippman 2001; Rao 2002)
Sustainable supply chain (Linton et al. 2007)
Sustainable supply network management (Cruz & Matsypura 2009; Young & Kielkiewicz-Young 2001)

Table 3. Definitions of green supply chain management

“The term ‘green supply’ indicated supply chain management activities that are attempts to improve the environmental performance of purchased inputs, or of the suppliers that provide them. Two main types of green supply can be identified. The first is termed greening the supply process, while the second is product-based green supply.” (Bowen et al. 2001)
“The concepts pertaining to greening the supply chain or supply chain environmental management (SCEM) are usually understood by industry as screening suppliers for their environmental performance and then doing business with only those that meet regulatory standards. The driving forces for implementing the concept into the company operations are many and comprise a range of ‘reactive regulatory reasons to proactive strategic and competitive advantage reasons.” (Rao 2002)
“The fully integrated, extended supply chain contains all of the elements of the traditional supply chain, but extends the one-way chain to construct a semi-closed loop that includes product and package recycling, re-use, and/or remanufacturing operations” (Beamon 1999)
"Environmental supply chain management (ESCM) for an individual firm is the

set of supply chain management policies held, actions taken, and relationships formed in response to concerns related to the natural environment with regard to the design, acquisition, production, distribution, use, reuse, and disposal of the firm's goods and services". (Zsidisin and Sifred 2001, p. 69)

Seuring & Müller (2008) made an expection to the definition of sustainable supply chain management: "as the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e. economic, environmental and social, into account which are derived from customer and stakeholder requirements." In their definition it was also able to integrate green supply chain management as one part of the wider field and not other way around.

In any case, the main goal of all supply chain operations are seen from organization's contribution towards customer satisfaction (Seuring 2004). In other words consumer pressures and the regulatory requirements are driving green supply chain management the same way as conventional supply chains. As Wilkerson (2005) said it is in fact a business value driver and not a cost centre. That is also why there is a need for establishing a solid connection between increased competition, economic performance and green supply chain management (Rao 2005). Before going in to these it is important to go through the elements of green supply chain and the greening of those elements.

2.2 Elements and greening of GSCM

Green supply chain management can be divided in to different elements but in this thesis I follow the classifications of Sarkis (2012) and Rao (2005) and mix these together to get a better picture of the elements. In figure 2 can be seen the most important functional activities and relationships in supply chain with the internal organizational unit at the center. Each of these phases can have greening functions and the more companies embed those the greener the supply chain management will be.

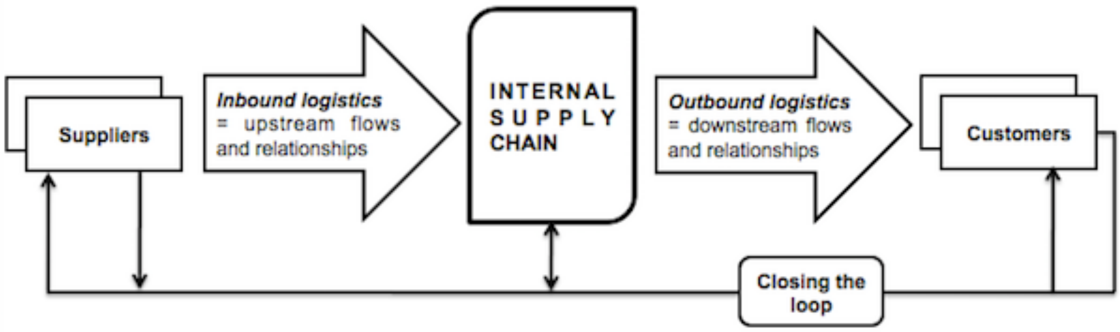

Figure 2. Elements of Green supply chain management. Modified from Sarkis 2012 & Rao 2005.

The basics of the figure 2 classifications are the same as Rao stated in (2005). He said that green supply chain management encompasses environmental initiatives in:

- Inbound logistics
    - Upstream flows and relationships
- Production or the internal supply chain
    - Internal activities
- Outbound logistics; and in some cases reverse logistics, including materials suppliers, service contractors, vendors, distributors and end users working together to reduce or eliminate detrimental environmental impacts of their activities
    - Downstream flows and relationships

2.2.1 Inbound logistics

Inbound logistics or in other words upstream flows and relationships essentially comprise of green purchasing activities that are adopted by organizations in response to global concerns of sustainability and environmental regulations. Min

& Galle (2001) defined green purchasing as "an environmentally-conscious purchasing practice that reduces sources of waste and promotes recycling and reclamation of purchased materials without adversely affecting performance requirements of such materials". These green purchasing strategies revolve around supplier collaboration such as outsourcing and focus on evaluation of suppliers' environmental performance and assisting suppliers to improve this performance. Therefore the involvement of supplier is crucial for achieving such goals. (Rao 2005)

Hines and Johns (2001) examined more closely the strengths and weaknesses of the supplier collaboration. The strengths of supplier monitoring are that it is proactive, non-threatening, shares potential benefits and builds teamwork. However weaknesses of this approach lie in resource and cost implications and in the lack of physical facilities and mentoring skills. Based on Hines and Johns (2001) and Rao (2005) there are six factors to improve the greening of the inbound phase of a green supply chain:

1. Holding awareness seminars for suppliers and contractors
2. Guiding suppliers to set up their own environmental programs or to accredit to an environmental management standard such as ISO 14001
3. Bringing together suppliers in the same industry to share their know-how and problems
4. Informing suppliers about the benefits of cleaner production and technologies
5. Pressuring suppliers to take environmental actions
6. Choice of suppliers by environmental criteria

Min & Galle (1997) actually explored green purchasing strategies among industries of heavy producers of scrap and waste in which Kemira, UPM and Fortum could be said to belong. They identified that the most significant barriers to green purchasing are uneconomical recycling and re-use and the high cost of environmental programs. These are the same reasons, as we will find later in the thesis when going through the early annual reports of mentioned companies.

2.2.2 Internal supply chain

Internal supply chain activities are related to operations management and production in the organization. In green supply chain management these include concepts such as cleaner production, research and design for environment and remanufacturing which all happen inside the internal organization even though the definition of this may not always be clear. For example closing the loop i.e. reverse logistics is a part of the internal supply chain because the wastes generated are processed and recycled back into the production phase. Still depending on the purpose, all of these processes could be defined from either services or manufacturing perspective. (Rao 2005; Sarkis 2012)

Based on Rao (2005) and Powell (1995) there are eight factors that can measure the greening of the production phase:

1. Environmentally friendly raw materials
2. Substitution of environmentally questionable materials
3. Taking environmental criteria into consideration
4. Environmental design considerations
5. Optimization of process to reduce solid waste and emissions
6. Use of cleaner technology processes to make savings in energy, water and waste
7. Internal recycling of materials within the production phase i.e closed loop
8. Incorporating environmental total quality management principles such as employee empowerment to increase employee’s involvement in design, planning and decision making

2.2.3 Outbound logistics

Outbound logistics are relationships and flows that are utilized by downstream customers who may be individual or commercial consumers. These include environmentally friendly activities such as distribution, transportation, warehousing, packaging and green marketing. These comprehend also waste exchange and reverse logistics that are part of the waste management. (Rao 2002; Sarkis 2012) In order to improve environmental performance of an organization various compromises are needed between logistics functions and environmental considerations because the greatest pressure towards sustainability comes from the customers (Wu & Dunn 1995).

Green marketing or in other words environmentally based marketing has a really important part in environmental innovation and competitive advantage (Menon & Menon 1997). Also environmentally friendly transportation system plays a critical role and the essential elements are the type of transport, sources, fuels, infrastructure and operational practices. (Rao 2005) Therefore the variables for greening the outbound function are:

1. Environmentally friendly waste management
2. Use of environmentally friendly transportation
3. Environmental improvement of packaging
4. Eco-labeling
5. Recovery of company’s end-of-life products
6. Providing consumers with information on environmental friendly products and production methods

2.2.4 Closing the loop

Closing the loop means that the supply chain process continues also after the customer, including reverse logistics such as recycling and remanufacturing. This is actually quite a new way of thinking, because in a traditional forward supply chain the customer is typically the end of the process. Even though it is clear that closing the loop is environmentally friendly much of the resarch has been focusing only on the business benefits. (Guide et al. 2003) The closed loop relationships are a part of every element of the supply chain and the relationships may be direct between organizations and its suppliers and customers, or only internal. (Sarkis 2012)

2.2.5 Recycling and re-use

According to Thierry et al. (1995) the "purpose of recycling is to reuse materials from used products and components." These materials can be reused in the original production processes depending on the quality of materials or in production of other parts. Recycling begins after the dissemblation of products. Re-use can be also distribution or selling used components and products as they are and thus no additional processing is required (Beamon 1999).

2.2.6 Remanufacturing

The focus on remanufacturing is to manufacture as good as new products from the used ones. It often means radical rethinking of products, their life cycle and production. It is expected to contribute to sustainability by saving energy resourcs and material as well as decreasing waste. (DemaNET 2014) In the process used products are often disassembled completely and all parts and modules are inspected extensively and the outdated parts are replaced with new ones. Remanufacturing is also possible to combine with technological upgrading. (Thierry et al. 1995)

2.3 Environmental management systems

As earlier stated, the roots of green supply chain management are in environmental management and therefore it is essential to examine the history and nature of environmental management systems to better understand green supply chain management.

The idea of environmental management is to encompass all efforts to minimize negative environmental impact of organization's operations. This includes reducing risks & costs, enhancing corporate image and improving marketing advantage (Klassen & McLaughlin 1996). Environmental management systems (EMS) are made for this and are strategic management approaches that define how an organization addresses its impacts on the environment. (Darnall 2008) The traditional view of environmental management has been that any actions which improve the environment are detrimental to business and that is why many organizations think green initiatives as trade-offs between environmental performance and economic performance. In worst cases it has led to situations where companies have decided it was better to pollute and pay a small fine instead of finding ways to prevent or eliminate the waste. (Walton et al. 1998; Klassen & McLaughlin 1996) Especially managers saw environmental management as a compliance with environmental regulations which involved tradeoffs between environmental and economic performance (Walley 1994).

Environmental management systems consist of a collection of assessments, internal policies, plans and implementation actions which affect the organization and its relationships with the natural environment (Coglianese & Nash 2001). All environmental management systems involve establishing an environmental plan or policy even though the specific institutional features differ across organizations (Darnall 2006). It indicates that the organization has implemented a management system that documents the organization's pollution impacts and aspects and identifies a pollution prevention process that is continually improved. (Bansal & Hunter 2003; Darnall 2006) It is especially important when suppliers are located geographically in a great distance such as Finnish companies having suppliers in India. (Rao 2005) The world's most recognized framework for environmental management systems is ISO 14001 (ISO 14000 family 2009).

2.3.1 ISO 14001

ISO 14001 certification standard was developed by the Internal Organization for Standardization (ISO) in 1996. The focus of the standard was on the processes of the creation, management and elimination of the pollution which meant that it was basically generated to be an effective tool for managers to profit from the waste reduction. (Melnyk et al. 2003) As Boiral (2007) said the adoptation of ISO 14001 was ”a ceremonial behaviour intended to superficially show that the certified organizations conformed to the standard”. Even though he proved that the adaptation also has ambiguous effect on environmental management practices and performances if used wisely. There has also been a radical change in management’s views and it has become clear that ISO 14001 environmental standard brings real benefits. For example it is a way to improve overall performance because without a formal environmental management system there may be no other way to obtain valuable information. (Melnyk et al. 2003)

As a proof of this at the end of 2007 over 150 000 companies in 148 countries and economies had certified to ISO 14001. (ISO 14000 family 2009). At the end of 2013 the number of companies was already over 300 000. (ISO Survey 2013)

2.4 Environmental & economic performance

Organizations with environmental management systems can increase profits and enhance corporate image while following environmental regulations. When wastes are minimized in environmental management it results in better utilization of natural resources which leads to improved efficiency and higher productivity and thus reduces operating costs (Klassen & McLaughlin 1996). Environmental management systems have also been associated with easier access to new markets and improved customer satisfaction (Darnall et al. 2001)

Environmental requirements are often based on the best available technologies that also offer competitive advantage (Klassen & McLaughlin 1996). This is why environmental management systems have been recognized to have stronger environmental performance than other voluntary environmental techniques like corporate environmental reporting (Annandale et al. 2004). Even though according to Krut & Gleckman (1998) this improved performance may only be identified within internal operations if at all. This is because EMS does not require evaluation of the environmental impact of the organization's supply chain (Handfield et al. 2004). Rondinelli & Vastag (2000) stated that for external stakeholders it could be impossible to find out if improvements in environmental performance actually occur.

Adopting EMS also has huge positive affects on utilizing green supply chain management that extends to the entire value chain. The relationship has significant environmental implications because together these systems provide more comprehensive means of establishing sustainability among networks of business organizations. (Preuss 2005) For example an organization that has environmental management system enhances its environmental performance significantly inside organizational boundaries, but its suppliers may not do the same without green supply chain management. Darnall (2008) and Rao (2005) also proved the linkage between green supply chain and competitiveness that was lacking empirically tested evidence from Klassen & McLaughlin (1996).

These are reasons why operations, purchasing and supply chain managers have seen the importance of integrating environmental management systems and green supply chain management together with related standards such as ISO 14001. This is also why the interest in green supply chain management has increased. (Seuring & Müller 2008) With the increasing acceptance of ISO 14001 environmental standard the role for supply chain management in organizational environmental practices is greater (Sarkis 2004). In the next section I focus on industrial symbiosis that adds a new level to green supply chain management and environmental management systems.

3. INDUSTRIAL SYMBIOSIS

The underlying concept of industrial symbiosis is the metaphor of an industrial ecosystem that functions like a natural ecosystem (Chertow 2000). In the literature of industrial ecology the term "industrial ecosystem" first appeared by Frosch & Gallopoulos in 1989: "In such a system the consumption of energy and materials is optimized, waste generation is minimized and the effluents of one process - whether they are spent catalysts from petroleum refining, fly and bottom ash from electric-power generation or discarded plastic containers from consumer products - serve as the raw material for another process." (Frosch & Gallopoulos 1989)

Similarly industrial symbiosis is designed on a metaphor of natural ecosystem in which dissimilar organisms mutually benefit from a relationship. In this symbiosis separate industries are engaged in a collective approach to gain competitive advantage by involving physical exchange of waste products such as low-grade heat energy, water and byproducts. The value is created from the waste products by forming creative inter-organizational relationships where these residual resources and byproducts of one firm are used as a feedstock for another. (Chertow 2000; Ehrenfeld 2004) In this thesis I have divided these relationships to input and output according to Chertow (2000) and Ehrenfeld (2004):

Industrial symbiosis

- Input
    - The use of residual resources and byproducts from other firms as their feedstock
- Output
    - The management of company's own residual resources and byproducts such as the level resource intensity (how many times used before disposal) and how productive is the use of waste

Industrial symbiosis is also often used alongside the term industrial ecology, which according to Jelinski et al. (1992) is a general approach to the implementation of sustainable manufacturing strategies. The exact definition is “a concept in which an industrial system is viewed not in isolation from its surrounding system but in concert with them. Industrial ecology seeks to optimize the total materials cycle from virgin material to finished material, to component, to product, to waste product, and to ultimate disposal.”

A prime example of an industrial symbiosis is an eco-industrial park because geographic proximity brings more synergetic possibilities. By working together businesses pursue a collective benefit that is greater than what could be achieved separately. In figure 3 you can see the symbiotic relationships of the most cited eco-industrial park in Kalundborg, Denmark. It consists of Kalundborg’s four main industries, which are 1500MW coal-fired power plant Asnaes, oil refinery Statoil, pharmaceutical and enzyme maker Novo Nordisk and plasterboard manufacturer Gyproc. Also several other users within the area e.g Kemira Acid Plant trade and make use of waste streams and energy resources and turn by-products into raw materials. (Chertow 2000, Ehrenfeld & Gertler 1997)

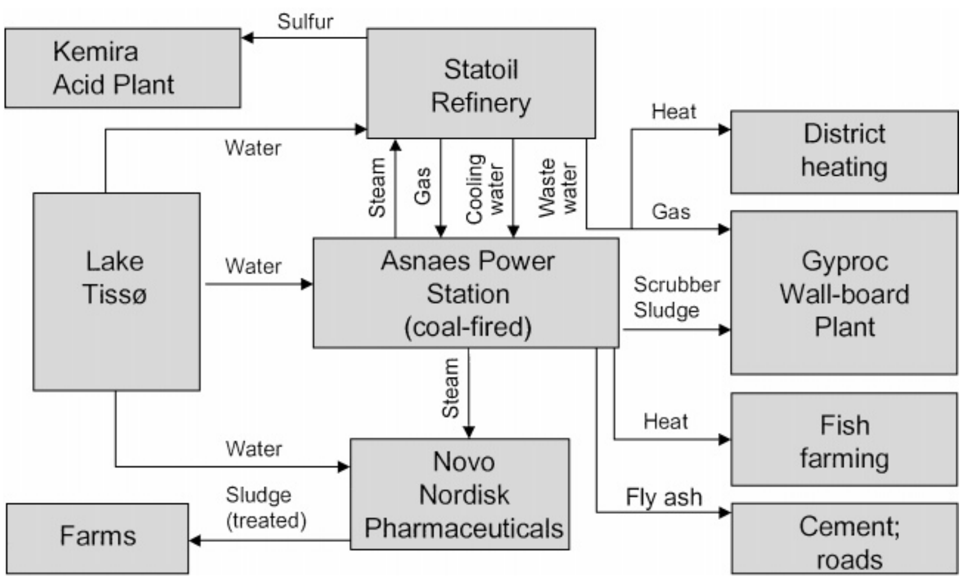

Figure 3. Industrial symbiosis at Kalundborg (Ehrenfeld & Getler 1997)

3.1 Relationship to supply chains

Industrial symbiosis and supply chains are both inter-organizational relationships that are based on product flows, but still differ significantly. Much of the research in these fields is aimed to reduce waste between organizations, even though there is surprisingly little consideration of industrial symbiosis within supply chain research. Yet, a deeper understanding and research in industrial symbiosis helps the understanding of sustainable development in supply chains. (Bansal & Mcknigt 2009)

These research streams also differ in the emphasis of the research: in supply chain research the aim is to reduce waste within a firm whereas in industrial symbiosis the aim is to reduce waste over the entire system of firms. In a conventional forward thinking supply chain this means that the waste reduction is done through pollution control and prevention. (Bansal & McKnight 2009) According to Vachon and Klassen (2007) pollution control is aimed to clean up the mess created by manufacturing processes because it captures, controls and treats pollution at the end of the pipe. Pollution prevention conversely happens at the source before pollution is created through product and process redesign (Klassen & Whybark 1999). Anyhow in these cases waste is treated as a pollution that is something to be eliminated instead of acknowledging its residual value like in industrial symbiosis (Linton et al. 2007). It is a problem because without waste or byproducts, the rich relationships that create industrial symbiosis cannot occur. Thus the preventation of pollution by individual firms in a supply chain could be counterproductive to industrial symbiosis since the manufacturing of waste could be below the levels of reusability. (Chertow 2000; Oldenburg & Geiser 1997)

Significant differences between industrial symbiosis and conventional supply chains also lie in the coordination mechanisms of firms according to Bansal & McKnight (2009). This is because industrial symbiosis requires a much tighter network of diverse relationships to function that emphasize community, cooperation and connectedness (Ehrenfeld 2000). This leads to a situation where partners involved are more likely to find innovative and mutually beneficial responses to problems through the rich information exchanged in symbiosis. In supply chains it might not be as easy because of the conventional techniques of information exchange such as forecasts, orders, inventory and marketing information. This type of information leads to a situation where the members of supply chains try to pursue the power of the chain and not the mutually beneficial outcome. (Bansal & McKnight 2009)

The high level of coordination in industrial symbiosis results in idiosyncratic relationships between partners and effective capitalizing on geographic proximity, excess resources and potentially useful wastes. This colocation is important for the symbiosis to occur as seen in figure 3 in Kalundborg because many waste products have short self lives, include hazardous properties, are difficult to transport or just have too low value to cover the expenses of transporting (CO_2 for example). These symbiotic relationships yield considerable heterogeneity in terms of material flows and organizational characteristics. (Bansal & McKnight 2009) This is a contrast to conventional supply chains that commonly source raw materials from the least expensive global supplier and sell products internationally (Roth et al. 2008). Therefore the inter-organizational structure of industrial symbiosis more closely resembles a dense web rather than a conventional chain.

The firms involved in industrial symbiosis also aim to extract as much value as possible from the inputs meaning a strong identification with the materials and resources they process. It is the opposite of conventional supply chains where firms focus on the output and identify with the end products (Bansal & McKnight 2009). Sarasvathy (2001) said that “symbiotic firms are governed by a logic of effectuation in which opportunities are created, rather than merely discovered”. This implies that firms involved in industrial symbiosis always aim to extract value from the available raw materials and seeing the potential value to find new uses for unused materials rather than manufacturing products to the exact needs of customers. (Bansal & McKnight 2009)

According to a new stream of research by Sarkis (2012), greening of the supply chain could also be a prerequisite for industrial symbiosis. This is because without green supply chain management finding the right partners to handle byproduct flows in an environmentally friendly way would be difficult. (Sarkis 2012; Tudor et al. 2007) Although in the context of supply chains the problem is generally that most of the attention has focused on the environmental dimensions while other aspects of sustainability have been neglected, that are emphasized in industrial symbiosis. (Bansal & McKnight 2009) Therefore in the next section I focus on the aspects of sustainability and how industrial symbiosis addresses these.

3.2 Sustainability

Industrial symbiosis produces sustainability and addresses all of its aspects that are environmental integrity, social equity and economic prosperity. Therefore I go through these principles that guide the research and practice of sustainability according to Elkington (1998) in table 4.

Table 4. Principles of sustainability

Environmental integrity "guards against excessive consumption and resource depletion in order to maintain the capacity of the earth's ecosystems to provide for human needs (Bansal 2005)"
Social equity "ensures that all people, including underprivileged people and future generations, are afforded equal opportunities (Bansal 2005)"
Economic prosperity "acknowledges that in order to provide a reasonable quality of life, goods and services need to be produced and distributed effectively and efficiently (Bansal 2005)"

The aspect of environmental integrity is maintained in industrial symbiosis with three mechanisms that minimize the system's ecological footprint (Bansal & McKnight 2009):

- Productive use of waste

    - The waste stays low because of the capturing of residual flows rather than emitting waste in nature (Huber 2000)
- High resource intensity
    - Intensity is increased as virgin resource streams are replaced with residual waste streams and thereby greater value is enabled to extract from existing resources in partner firms
      → Nature's resources are reused multiple times before disposal
- Accelerated biological degrading processes
    - Accelerated biological degradation of waste decreases the concentrations and toxicity of the emissions in natural systems

In addition to environmental integrity, industrial symbiosis also addresses the social and economic aspects of sustainability. Industrial symbiosis enhances social equity within communities by engaging many different types of relationships that form a dense network of interdependent firms. It encourages to a shared sense of community that engenders a collaborative and positive response to adversity. Simultaneously it also helps firms to build economic prosperity by generating revenues from resources that would otherwise be discarded. (Bansal & McKnight 2009)

Actually the focus on the system of firms in industrial symbiosis offers the added benefit of supporting economic prosperity and social equity and forms the foundation for sustainable development (Bansal & McKnight 2009). Allenby (1999) even hailed industrial symbiosis as the "Science of Sustainability" and Ehrenfeld (2000) said that industrial symbiosis is the model that advances the sustainability paradigm. In any case all these principles are interconnected which means that for example focusing on economic prosperity may undermine the environmental integrity even though it is definitely possible to construct win-win-win situations. Therefore in the next chapter I'm focusing on the challenges of implementing industrial symbiosis and after that how to overcome these challenges

3.3 Challenges of industrial symbiosis

It is hard to achieve the high degree of community, cooperation and coordination demanded by industrial symbiosis because of technical and social challenges. Technical challenges are connected to the quantity and quality of industrial byproducts and the social challenges to the reliability of partner firms to meet those standards. There could also be governmental regulations that make it harder for the symbiosis to occur because of the limits and restrictions of handling and transporting waste (Bansal & McKnight 2009; Cohen-Rosenthal 2000; Heeres et al. 2004; Oldenburg & Geiser 1997) In this section I'm focusing only on the technical and social challenges as seen in table 5 and table 6.

Table 5. Technical challenges of industrial symbiosis

Firms must ensure adequate supply of their byproducts to be provided to symbiotic partners
The quantity of the byproducts is determined by the demand of the core product and because of that, the quality of the byproducts could be compromised
The production processes often require inputs that conform to exacting quality standards
Wide quality variance can limit the success of many manufacturing processes

Table 6. Social challenges of industrial symbiosis

Personal relationships
Trust and cooperation among diverse partners can lead to a situation where relationships become embedded and inhibit adaptation and innovation to externally driven challenges and opportunities
Managers must take care of mutual interests in production decisions

These challenges limit the ability of the symbiotic system to respond to shocks. Therefore managers must monitor their own market but also their suppliers' markets that could be challenging if the knowhow of those markets is weak. Learning about those new markets consumes valuable managerial attention and makes it difficult to react quickly to downstream product changes. Similarly if the demand of company's main product is decreased, also byproducts are decreased. This could impose additional costs, as the recipient firms will have to source inputs from elsewhere. At its worst the failure of one company could cause reverberations through the system and lead to a collapse of the symbiosis. (Bansal & McKnight 2009)

3.4 Overcoming the challenges of industrial symbiosis

According to Cote and Hall (1995) and Chertow (2007) communities among diverse firms and industries are critical to industrial symbiosis and therefore the research has mostly focused on industrial parks. These parks have the physical infrastructure to share materials as well as social structures to facilitate collaboration, and even basic meetings can initiate symbiotic relationships. Therefore social structures such as professional associations that facilitate personal relationships are essential for flexibility.

The trust among partners is equally important and third parties such as industry associations and other coordinating organizations could help to build this trust, even though they can also make it more difficult depending on the situation. (Gibbs 2003) These organizations can for example facilitate the sharing of information (Heeres et al. 2004) or serve as anchor organizations to strengthen the relationships (Chertow 2000). After the establishment of trust it is vital to share data and critical processes regarding common operations. If the processes are well understood and waste readily apparent, less data is needed to share.

Consequently industrial symbiosis is more likely to occur when mutually beneficial relationships align the interests of all parties. The relationship must be symbiotic and not just the sinking of one firm's waste into another's production processes. For example a colocation of greenhouse beside an oil refinery is more interesting for the oil refinery if the greenhouse produces biofuels that the oil refinery could process and sell. (Bansal & McKnight 2009)

However a perfect symbiotic system between firms in which all wastes are internalized within the system and completely consumed is not known to exist. Even Kalundborg's eco-industrial park in figure 3 generates wastes through its member firm's production processes. Thus most firms do not rely purely on symbiotic model, but a hybrid form that integrates forward and reverse supply chains with industrial symbiosis. An example of a hybrid supply chain is when wastes of one firm are used as inputs for another firm in exchange of money. This minimal form symbiosis helps to contain the level of complexity that comes with interdependence. Therefore hybrid models are able to achieve many of the benefits associated with industrial symbiosis without compromising the resiliency associated with the inflexibility of industrial symbiosis. (Bansal & McKnight 2009)

3.5 Overview of literature

Before proceeding to the methodology part and the actual research, it is essential to conclude the most important parts of the theory and why it is important to study this subject through annual reports.

Green supply chain management consists of inbound logistics, internal supply chain and outbound logistics, which can all have greening components such as environmentally conscious purchasing practises, optimization of processes and environmentally friendly waste management. Industrial symbiosis on the other hand consists of input side that is the use of byproducts from another firm, and output side that is the management of company's own byproducts.

These research streams also differ in the emphasis of the research because in supply chain research the aim is to reduce waste within a firm whereas in industrial symbiosis the aim is to reduce waste over the entire system of firms. Thus the preventation of pollution by individual firms in a supply chain could be counterproductive to industrial symbiosis since the manufacturing of waste could be below the levels of reusability. It is a problem because without waste or byproducts, the rich relationships that create industrial symbiosis cannot occur. This is why I have studied the improvement of operations in green supply chain management and industrial symbiosis because those operations demonstrate how the chosen companies have addressed these issues and what could be learned for the future.

The reason why I have studied the improvement of operations in GSCM and IS through annual reports is that they are prime material to study firm’s strategies, organizational behavior and the interaction of their organizational field (Dirsmith & Covaleski 1983; Bettman & Weitz 1983). Annual reports also offer an easy access to comparable set of data and thus avoid sense-making bias often present during retrospective interviews (Osborne et al. 2001; Bettman & Weitz 1983). Also these reports describe what actions and initiatives corporations have adopted or will adopt to resolve new or emerging organizational milieus (Salancik & Meindl 1984).

4. METHODOLOGY

I examine the annual reports of three large Finnish industrial companies from 2004 to 2013 and use a structured content analysis to review their operations that are related in GSCM and IS. This research is based on annual reports that include sustainability reports and environmental reports of UPM, Fortum and Kemira. Altogether this makes 30 coded annual reports. In addition I have coded also environmental & corporate responsibility reports from UPM from 2004, 2005 and 2006 because those were not part of annual reports before 2007. Fortum and Kemira had included these reports in their annual reports from the whole time of research. The coded reports can be seen from table 7.

Table 7. Coded reports

	UPM structured content analysis	**Fortum structured content analysis**	**Kemira structured content analysis**
2004	Annual report, Environmental & corporate responsibility report	Annual report	Annual report
2005	Annual report, Environmental & corporate responsibility report	Annual report	Annual report
2006	Annual report, Environmental & corporate responsibility report	Annual report	Annual report
2007	Annual report	Annual report	Annual report
2008	Annual report	Annual report	Annual report
2009	Annual report	Annual report	Annual report
2010	Annual report	Annual report	Annual report
2011	Annual report	Annual report	Annual report

2012	Annual report	Annual report	Annual report
2013	Annual report	Annual report	Annual report

UPM is a pulp, paper and timber manufacturer, Fortum is an energy company and Kemira is a chemical industry group. I have chosen these three companies because they all represent different industries and thus give as wide image as possible based on their operations in green supply chain management and industrial symbiosis. Often GSCM and IS have been used side by side and thus some operations can be simultaneously part of green supply chain management and industrial symbiosis. I have chosen that ten years is a suitable time span to review these operations because in that time it is possible to see some improvement in their operations.

According to Weber (1990) content analysis is “a research method that uses a set of procedures to make valid inferences from text” such as annual reports. Even though annual reports offer an easy acces to comparable set of data those could be also used to portray the best possible image of the company and therefore could be criticized (Escobar & Vredenburg 2011). Abrahamson and Hambrick (1997) made a detailed account of the reliability of annual reports for the study of business strategy and concluded that for non-evaluative information such as actions taken by managers present in annual reports, the best analytical approach is an information processing interpretation such as content analysis. Later Duriau et al. (2007) reviewed the use of content analysis in annual reports and suggested that annual reports are a valuable source of non-evaluative information. Therefore non-evaluative examination of annual reports with structured content analysis gives the best possible information of the operations related to industrial symbiosis and green supply chain management. With the information of how the operations have improved it is possible to analyze how could the operations in green supply chain management and industrial symbiosis support each other in the chosen companies. Therefore also the causality between these two is valuable.

5. REVIEW OF ANNUAL REPORTS

In this chapter I code the annual reports of UPM, Fortum and Kemira based on the operations in green supply chain management and industrial symbiosis and how those operations have improved between 2004 and 2013. I start the analyzing of each company with genereal business development to demonstrate the magnitude of businesses and then move on to analyzing operations. In the coding of operations I will first present an overview of the progress and after that move on to more detailed research.

5.1 UPM

In 2004 UPM had production plants in 16 countries, employed 33,400 people and was one of the world's leading manufacturers of printing papers and a clear market leader in magazine papers. During the evaluation time UPM had to reorganize its business structure and in 2013 it consisted of the following business areas: biorefining (pulp, biofuels and sawn timber), energy, Raflatec, paper Asia, paper ENA (Europe and North America) and Plywood. In 2013 it had production plants in 14 countries and employed 21,000 people worldwide.

From figure 4 you can see that UPM's sales and operating profits have been quite stable during the evaluation time expect for 2009 when there was a global recession going on that affected also UPM. At the beginning of the time period in 2004, the sales were EUR 9.8 billion and operating profit EUR 0.6 billion while in 2013, the sales sales totalled EUR 10.1 billion with profit of EUR 0.7 billion.

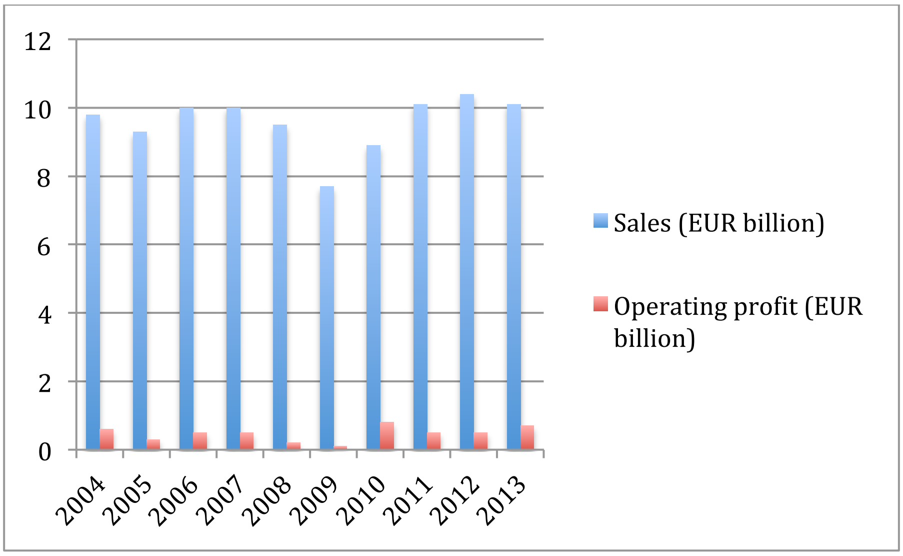

Figure 4. UPM's sales and operating profits between 2004 and 2013

In 2004 all UPM's pulp and paper mills, as well as the wood products division's production plants in Finland had environmental management systems approved by a third party while four of the converting division's plants had certified systems. Therefore in 2004 most of UPM's production plants were certified even though it was still seeking to deal with environment-related issues in compliance with ISO standard 14001.

In 2004 UPM was mostly self-sufficient in term of chemical pulp and electrical power because its activities were based on close integration of raw materials, energy and production as you can see from figure 5. Globally Group's self-sufficiency rate in electricity was 70%, as it was 100% in Finland.

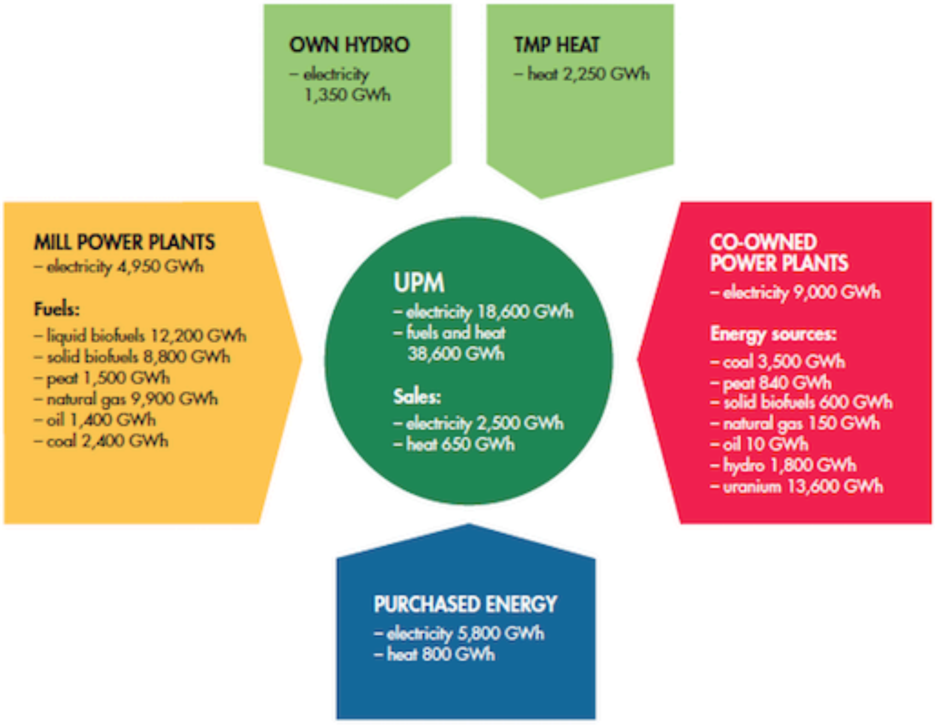

Figure 5. Energy sources and fuels at UPM in 2004

Even though UPM was mostly self-sufficient it was also one of the world's leading consumers of recovered paper, because recycled fibre is produced from that. Recovered paper was mostly used in Central Europe, where large amounts of that was available near the mills. To make the use of recovered paper possible, efficient collection and sorting systems were required as it must be in the recovery of end-of-life products in the outbound logistics of green supply chain.

In Finland, 71% of wood raw material was used for making paper and 29% for the manufacturing of wood products. Besides the supply to own mills, forestry department also supplied 4.4 million m^3 of wood to associated companies and other outside customers. This was possible because of worldwide logistics network and high proportions of shipments made by sea.

In 2005 virtually all production was based on wood fibre that was a renewable resource. Only one tenth of the wood consumed by the mills was acquired from the Company's own forests or from forest where it had felling rights. Almost 90%

of the chemical pulp came from company-owned or associated mills and over a quarter of the fibre used was recycled. The end user could also recycle almost all of the UPM's products by burning or composting. UPM also acquired 99% of the shares of a Russian logging company and established its own wood procurement company in Russia called UPM-Kymmene Forest Russia. This helped to ensure the availability and traceability of high-quality timber for production plants in Russia and for the company's mills in Finland. In 2005 over 75% of the fuels used by UPM's mills in Finland were CO_2 neutral while the corresponding proportion in the Group was about 50%.

In 2006 UPM got the European Eco-label for its fine papers that were sold under its own trademark and was a sign of greening its outbound logistics. In 2007 euro strengthened and the price of wood increased, that meant e.g. the failure of cost saving programs. The strengthening of Euro also increased the market price of electricity, but because UPM was almost self-sufficient in energy production it mitigated the effects of the price rise.

In 2008 the rapid slowdown of economy and high wood costs decreased profits. UPM also had to reorganize its business structure and they closed down the least competitive paper and pulp capacity in Finland. In 2009 this led to a situation that UPM labeled itself as a leading bio and forest industry company and created a new category called UPM – The Biofore Company. Also in 2009, UPM and SGS that was the world's leading verification company finalized a global landmark agreement on multisite certification for pulp and paper products. This meant that old individual chain of custody certificates were replaced with a single global system that guaranteed the origin of UPM products and thus made the greening of the chain easier.

In 2010 most significant investment was the acquisition of Myllykoski and Rhein Papier with enterprise value of the business about EUR 900 million. It consisted of seven paper mills in Germany, Finland and United States. Because of the acquisition, in 2011 Group had production plants in 16 countries and employed approximately 24,000 people. UPM also started to use Ecodesign that is an important part of green supply chain. It meant that environmental aspect were systematically integrated into product design at an early stage so that also R&D adopted ecodesign in the early development process continuing through the whole lifecycle.

In 2012 UPM became a member of Cleantech Finland and had production plants in 17 countries. In 2013 UPM had to close down some paper mills in France and Germany and thus it only had production plants in 14 countries totalling 21,000 employees.

In 2013 UPM was the world's largest user of recycled paper for the production of graphic papers. In 2013 the total consumption of recovered paper was about 3.5 million tonnes and has stayed almost the same for the last three years and during 2003 – 2010 it has been about 2.8 million tonnes. The efficiency of paper recycling depended on the local infrastructure. The recycled paper used by UPM was mostly purchased from Europe, where the most significant suppliers were local authorities, waste management companies and printing houses. UPM aimed to optimize the value chain of paper for recycling by focusing on local supply close to the mills with minimal cost and environmental impact. This procedure was also an example of greening the supply chain with the help of symbiosis between firms.

Ecol-labelling was similarly an important part in the greening of supply chain and in 2013, 75% of UPM's overall sales of paper, chemical pulp, plywood and timber products were eco-labelled. Most of the production sites were also environmentally certified by then.

5.1.1 Green supply chain management

The majority of UPM's greenhouse gasses were caused by energy generation at its pulp and paper mills. The choice of fuels, combustion technology and flue-gas purification were the primary ways for UPM to reduce these emissions and green their supply chain.

Starting from 2012 UPM had to report exact amounts of direct and indirect greenhouse gas emissions. For example in 2012 direct CO_2 emissions were 3,800,000 tonnes, as power purchased from the grid resulted in additional 3,000,000 tonnes and transport and raw material production in additional 4,100,000 tonnes of indirect emissions. Despite these enormous additional amounts the only greenhouse gas statistics UPM has presented from the research time are paper mills' carbon dioxide emissions that can be seen from figure 6. The left side of the figure is the amount of paper mills' carbon dioxide emissions in thousands tonnes and the right side the amount of paper produced in thousands tonnes. These are shown together because the amount of paper produced is in correlation with the carbon dioxide emissions of the mills.

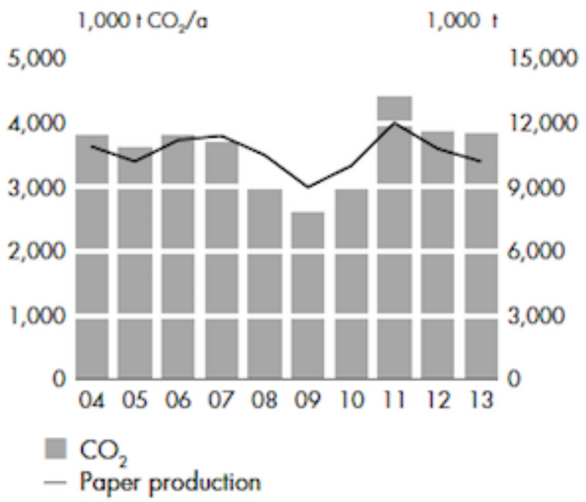

Figure 6. Paper mills' direct carbon dioxide emissions and the amount of produced paper 2004 – 2013

The decrease of emisions in 2008 and 2009 was because of the global recession that affected the amount of paper production. As an example in 2009 combined heat and power (CHP) plants represented one third of UPM's total power generation, and 63% of fuels used were biomass-based. CHP plants are also good examples of the optimization of processes because of the effective use of energy. The huge increase of emissions from 2010 to 2011 was because of an acquisition of paper mills with high shares of fossil fuels. In 2013 the direct carbon dioxide emissions were 3,800,00 tonnes, as the power purchased from the grid added 3,000,000 tonnes and transport and raw material production added as much as 7,000,000 tonnes of indirect emissions. In 2013 biomass-based fuels made up approximately 84% of the fuels used by UPM in Finland and approximately 67% of those used worldwide in 2013.

Even though UPM didn't report exact amounts of greenhouse gasses before 2012, it shifted its strategy to biofore-company during the ten years of observation. In the following figure 7 you can see the amounts of environmental investments and management costs each year that also reflect the investments in greening the supply chain and therefore I will also go through the most important environmental investments.

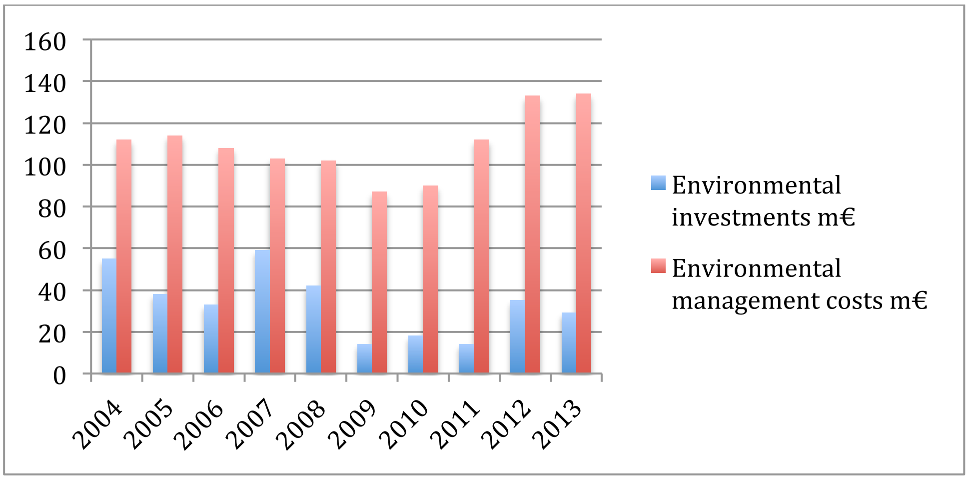

Figure 7. UPM's environmental investments and management costs in EUR million 2004 – 2013

The most important investment in the beginning of the review in terms of environmental impact was the modernization at Pietarsaari pulp mill that lowered emissions drastically. Most of the biggest environmental investments during the research time were related to building and rebuilding of plants, mordernization, effluent and sludge treatment and e.g. refurbishment projects.

The decrease of management costs starting from 2006 was partly because of decreased amounts of waste management, as the decrease of investments starting from 2008 was because of beginning global recession that meant less production. After the recession in 2010 there was a rise in the production that also meant increased investments for example in waste and effluent management that continued until 2012. Because the operations in green supply chain management had improved the rise in the production was seen as decreased amounts in waste sent to landfills.

From figure 8 you can see the amounts of total waste sent to landfills between 2004 and 2013 and how the greening efforts have influenced the amount of wastes. The huge rise in 2006 was because the reuse plans didn't materialize in 2006 as in 2013 the reason was that former re-use possibilities for ash ceased at one of UPM's paper mills. Otherwise there has been a clear decrease of landfilled wastes from 2006 that is a sign of optimization of processes and greening of the supply chain, because wastes were used as resources rather than landfilled. The effective use of industrial symbiosis also decreases the total waste sent to landfills. Next I discuss in more detail about figure 8 and the changes.

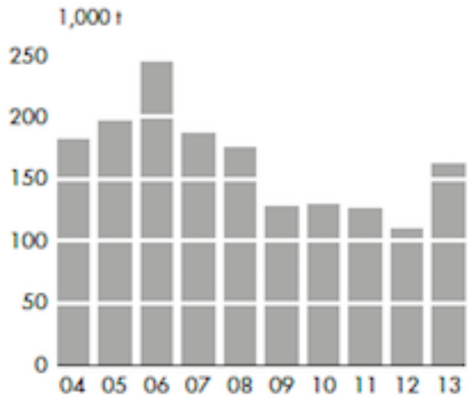

Figure 8. UPM's total waste sent to landfills in 1,000 tonnes 2004 – 2013

The ways to reduce waste volumes and to make use of waste were heavily under development in 2004 and 2005. Most of the solid waste from pulp and paper mills was ash and the potential of using waste depended on the country and its legislation and practices. Especially in Finland the amount of waste taken to landfill sites needed to be reduced. In 2005 the best way to reuse residues that contained plastic and silicone was to combust them to generate energy even though there were ongoing projects for process optimization, improved sorting and increased recycling. The overall reutilization rate of all solid waste form the pulp and paper mills was 85% and about 70% at the converting plants, sawmills and plywood mills. These processes were examples of gradually greening the supply chain because the wastes were used inside firm's own processes even though not very effectively.

In Europe, local authority was usually responsible of the waste management even though the recovery solutions varied in different countries. Therefore UPM mostly procured its recovered paper from local authorities or waste management companies. In 2006 the reduction of landfill waste didn't succeed due to the fact that the reuse plans did not materialize and a total of 240,000 tonnes of solid waste was taken to landfills of which the most significant individual solid waste fraction was still ash. In 2009 almost 90% of production waste was reused or recycled that was a good percent. Compared to 2008 the total volume of landfill waste decreased by 27% to 120,000 tonnes that was also due to lower production volumes and UPM's efforts to find new reuse options for waste.

Ash from mill power plants constituted the most significant amount of solid waste and as much as 1,360,000 tonnes of solid waste was reused or recycled. 2011 was the first year with amounts of solid waste recycled. This meant that over 90% of all UPM's production waste was reused or recycled mostly as raw material or in energy generation.

The amount of solid waste sent to landfills was 109,000 tonnes and decreased from previous year because of the increased use of ash for land construction and capping. Also most of the production sites have reduced the volume of solid waste by improving the handling and sorting of waste at the source. Even though this amount included only process and production waste, because additional 70,000 tonnes of construction waste resulted from the demolition of old paper machine building at UPM Blandin.

Research and development is also and important part of green supply chain management and UPM's direct R&D expenditures have been approximately in the same level during last ten years as seen from figure 9. The decrease of R&D costs in 2012 and 2013 is partly because UPM's development expenditure increased in developing countries. Those expenditures included negative operating cash flows and capital expenditures in addition to direct R&D costs. In 2012 UPM spent EUR 81 million in existing and developing businesses and in 2013 as much as EUR 155 million.

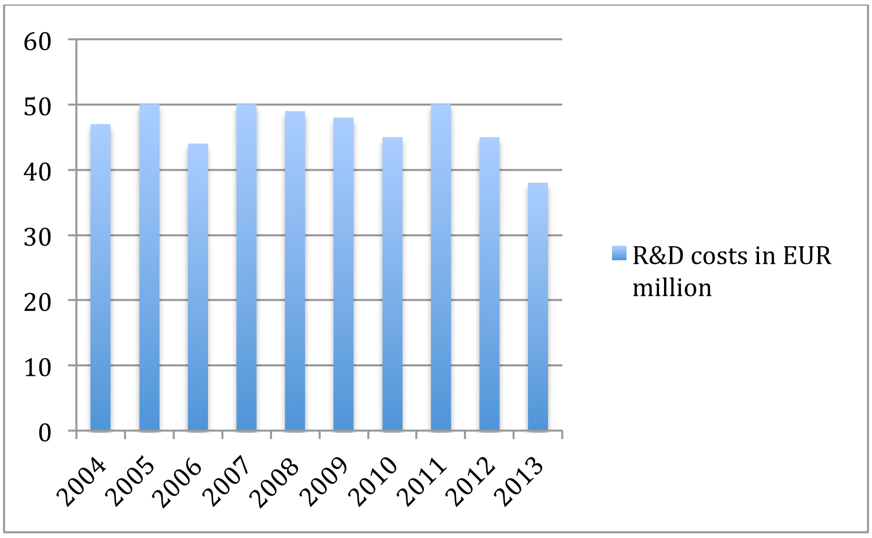

Figure 9. UPM's research and development costs in EUR million 2004 – 2013

In 2008 UPM started to sell new UPM ProFi that were high quality wood plastic composite products made mainly from the surplus paper and plastic left over from the production. This was an example of the results of research and development that greened the supply chain with effective reverse logistics. UPM also manufactured a wide variety of RFID tags and inlays that were designed for product identification for example in supply chain management and transportation to make the processes more effective.

5.1.2 Industrial symbiosis

Most of the solid waste from pulp and paper mills is ash and it is mostly utilized in earthwork operations outside factories in cement and brick industry depending on the country and its legislation practices. Therefore the utilization rate of ash is a good indicator of industrial symbiosis.

Unfortunately from 2004 there wasn't any information about the utilization rates because the ways to reduce waste volumes and to make use of waste were heavily under development. After that the utilization rate has been increasing almost all the time. During 2010, 2011 and 2013 there wasn't any information about exact utilization rates of ash, only utilization rate of the total waste of which ash has the most significant proportion and thus it replaced the utilization rate of ash in figure **X**. For example in 2009, 95% of ash was utilized as 90% of the total waste was utilized. In 2006 the utilization rate of ash was decreased a bit because the number of landfill sites decreased and thus also the earthwork use of ash decreased. These can all be seen from figure 10.

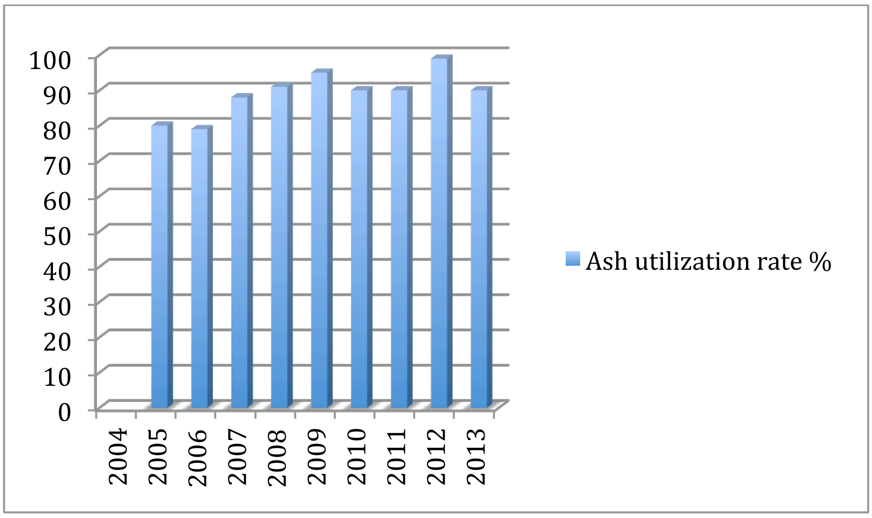

Figure 10. UPM's utilization rates of ash in percentages 2004 – 2013

In 2006 the most significant individual solid waste fraction was ash and about 79% of the ash was utilized in earthwork operations and in cement and brick industry for example. Particularly in Finland ash has been used when company's old landfill sites were closed down and therefore the reuse of ash hasn't been sustainable in the context of symbiosis. However because the number of landfill sites to be closed down has decreased also the reuse of ash has decreased. That has forced UPM to increase co-operation with new partners to increase the reuse of ash in a sustainable way. It is a perfect example of industrial symbiosis because the flow of byproducts generated new relationships.

In 2007, 88% of the total ash volume from UPM was reused in different applications but there wasn't any information about how the ash was reused. The total amount of solid waste taken to landfills decreased by 23% to approximately 190,000 tonnes and consisted primarily of ash from mill power plants.

In 2008 almost all organic production residues were used in energy generation at the mills. Therefore ash left over from the energy generation at the power plants was the most significant solid waste fraction at UPM. In 2008, 91% of the total ash volume was reused in different applications.

In 2010 the percentage of waste reused or recycled stayed at 90% of which most was still ash and was reused in applications that ranged from road building to construction aggregates.

Again in 2010 ash from mill power plants constituted the most significant amount of solid waste and as much as 1,360,000 tonnes of solid waste was reused or recycled. The following year was the first reported year with amounts of solid waste recycled. This meant that over 90% of all UPM's production waste was reused or recycled mostly as raw material or in energy generation. 2011 was also the first year for UPM's Shotton paper mill in the UK for operation. It had the capacity to sort 270,000 tonnes of comingled materials sourced from across the UK, with recovery rates at 99%.

In 2012 the total amount of solid waste or in other words by-products reused or recycled was 1,270,000 tonnes meaning over 90% of all UPM's production waste. Ash was the most significant proportion of this and actually 99% of the ash was reused.

Approximately 90% of all production waste (1,200,000 tonnes) was reused in 2013, of which ash was still the most significant proportion. Also almost all organic production residues including bark and wood residues, as well as fibre-containing solids from deinking and effluent treatment were used in energy generation at mill sites. UPM has also constantly developed innovative ways to reduce its own waste and to reuse it in new products such as diesel made of crude tall oil and UPM ProFI.

5.2 Fortum

In 2004 Fortum was the leading energy company in the Nordic countries and the other parts of the Baltic Rim. Fortum's main products were electricity, heat and steam, traffic fuels and heating oils. It's competitiveness in the power and heat business was based on a pan-Nordic concept that had a broad customer base and good knowledge. The main development for Fortum happened in 2005, when the oil business was seperated through a share dividend and a sale of shares. The reason was that both the oil and power businessses were very capital intensive and thus Neste Oil continued the oil business and Fortum focused on the refining of natural energy sources into electricity and heat. The seperation can be seen from figure 11 as a huge drop of sales from EUR 11.7 billion to EUR 3.9 billion. After the seperation the increase of sales have been quite stable. In 2013 the sales was EUR 6.1 billion while operating profit was EUR 1,6 billion.

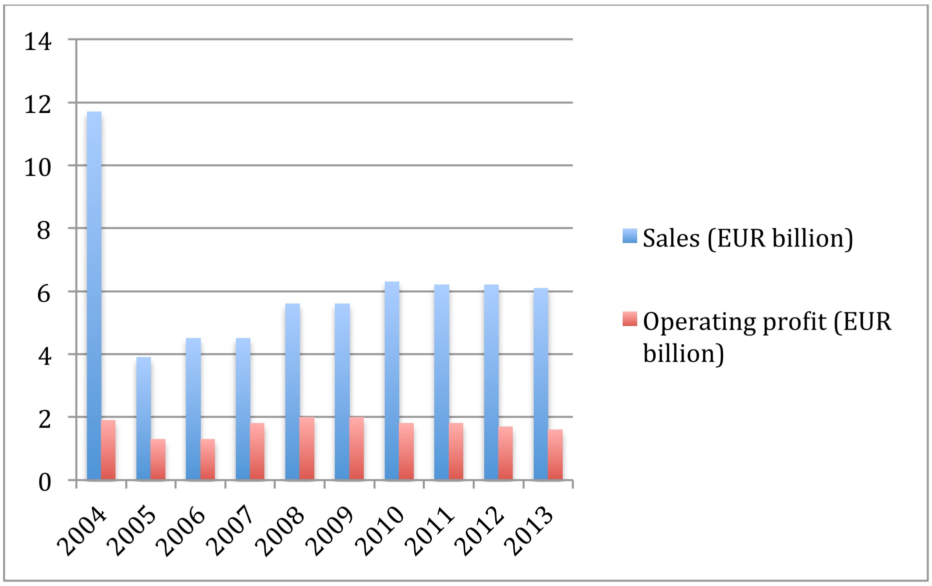

Figure 11. Fortum's sales 2004 – 2013

Fortum had also gradually increased its ownership in Russian companies. In 2005 Fortum increased its ownership in OAO Lenenergo to over 33% and acquired 25% of the shares in Kolenergo. Through Lenenergo Fortum was now a part owner of TGC-1 that generated most of its capacity with hydropower. Because of this also Fortum's own hydropower capacity increased.

In 2008 Fortum acquired Russian TGC-10 that produced all of its power with fossil fuels. The acquisition increased CO_2 emission drastically and almost doubled Fortum's heat production capacity, increased power generation capacity by 25% and added 7,000 employees. This acquisition also increased the sales.

Fortum invested actively in CHP plants for more effective use of energy and in 2009 Fortum owned and operated 22 CHP plants and several hundred heat plants in the Nordic and Baltic countries including also Poland. Fortum also joined the Cleanthech Finland R&D-initative.

2010 was the first year when Fortum reported about exact amounts of environment, health and safety investments. Fortum's EHS investments in 2010 totalled EUR 91 million and were mostly related to new CHP investments.

However because the expenses were not completely uniform throughout Fortum, the alignment of expenses was impossible and is thus left out of the research.

Altogether in 2013 Fortum produced energy in CHP plants in eight countries**.** Still the shares of biomass and waste derived fuels were minor in the fuel mix of CHP production that consisted mostly of natural gas because of the huge production of Russia: natural gas 76%, coal 13%, waste-derived fuels 3%, biomass and bioliquids 7% and peat 0,6%.

5.2.1 Green supply chain management

Fortum's carbon dioxide emissions are important in the context of green supply chain and can be seen from figure 12. The decrease from 2004 to 2005 was because of the separation of oil business and the focus in low carbon energy sources such as nuclear power and hydropower. The increase of emissions in 2006 was because of a low production of hydropower in the Nordic market area. Thus the overall efficiency of fuel use decreased as a result of the use of condensing power plants. Emissions from Fortum's own power plants totalled 11.0 million tonnes that was 70% higher than in 2005.

In 2008 there was also a clear increase emissions until 2010 that was because of the acquisition of Russian TGC-10 that generated all of its energy with natural gas. The acquisition almost doubled Fortum's heat production capacity and increased power generation capacity by 25%. By 2010 the total CO_2 emissions including Russia had increased to 25.3 million tonnes. Russia's share was 14.6 million tonnes as the rest was from Europe.

Starting from 2011 Fortum had to report also the total greenhouse gas emissions according to sustainability reportin guidelines (GRI) that included direct and indirect CO_2 emissions as well as other greenhouse gasses that were minor compared to carbon dioxide. That is the reason why and I'm not analyzing those more carefully because the direct emissions accounted for 80% of the greenhouse gas emissions. These are the same emissions that I have been reporting and originate from the burning of fossil fuels for the production of energy. The indirect emissions originate from the purchased electricity, steam and heat and accounted for 1% as the rest indirect emissions with share of 19% originate from the production and transportation of fuels and for example from the use and processing of products. The share of direct and indirect emissions was approximately the same each year and therefore it is not necessary to research any further because direct carbon dioxide emissions reflect the improvements.

In 2012 Fortum's CO_2 emissions from production totalled 20.7 million tonnes, of which 76% resulted from Russian operations. The total greenhouse gas emissions including direct and indirect emissions totalled 26 million tonnes. The efficiency of total fuel use was 64,2% while the five-year average target was 70%. CHP plants accounted for 32% of electricity production and 79% of heat production.

In 2013 Fortum emitted 21.4 million tonnes of CO_2 and from this amount 72% resulted from the Russian operations and 16% from Finland. The total amount of greenhouse gas emissions including direct and indirect emissions totalled 27.5 million tonnes.

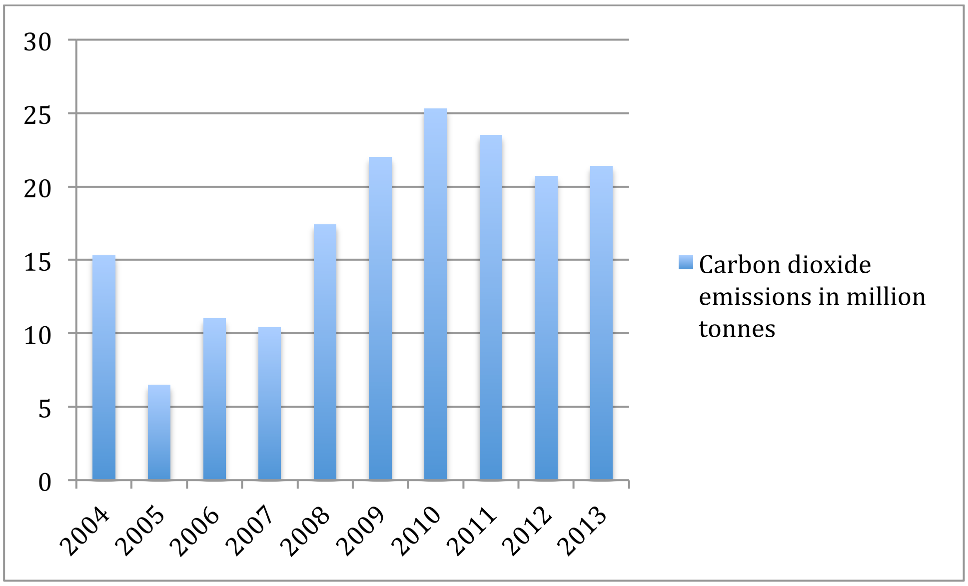

Figure 12. Fortum's CO_2 emissions in million tonnes 2004 – 2013

Fortum had ISO 14001 certificates in 95% of its operations in 2013 that included also Russia. This was a big improvement because in 2005 Fortum had certification only in the Nordic countries even though the carbon dioxide emissions were much bigger in 2013 than in 2005. Emission trading started also in the EU in 2005 and in the long-term it was said to be the most cost effective way of steering towards lower CO_2 emissions. These emissions were harmonized inside EU to contribute to European power market integration. Fortum also started the marketing of eco-labelled electricity as a part of greening its supply chain and was the biggest seller eco-labelled energy in Nordic countries.

Yearly refurbishment projects at hydropower plants were important for the optimization of processes and added approximately 5 GWh to 10 GWh of addiotional renewable energy, but because the amounts were quite minor compared to overall I'm not going to focus more on these projects.

In 2013 Fortum's power generation was 65.7 TWh and heat production 42.8 TWh. In total Fortum's direct primary energy consumption in own energy production was approximately 140 TWh and divided as seen in table 8 that includes also 2012 and 2011 according to GRI guidelines. The amount of waste-derived fuels was only 2.8 TWh meaning 987,000 tonnes of waste used.

Table 8. Fortum's direct energy consumption by energy source 2011 – 2013

TWh	2013	2012	2011
Natural gas	73.6	76.0	75.6
Nuclear fuel	23.1	24.7	24.3
Hydropower	14.4	18.3	17.1
Coal	17.9	14.2	21.8
Biomass and biofuels	6.8	6.1	6.2
Waste-derived fuel	2.8	2.3	2.5
Peat	0.6	0.7	1.2
Fuel oil	0.4	0.6	1.3
Other fuels	0.1	0.1	0.2
Total	**139.7**	**143.0**	**150.2**

The waste management accounted for EUR 5.2 million as it was EUR 4.0 million in 2012. There was a big rise of air pollution control from EUR 6.1 million in

2012 to EUR 12.9 million because Fortum had to achieve its goals for greenhouse gas emissions.

In other areas Fortum's reporting wasn't very consistent and therefore it was harder to compile the findings. For example from 2007 to 2009 there wasn't any information about waste management or by-products in the reports and therefore it was impossible to conclude those years in the findings. One reason for this could be the acquisition of Russian TGC-10 in 2008 that affected for many years and increased the emissions drastically and thus some key figures were kept hidden. Of course the focus was also in the transaction and in the transition towards natural gas and surely took lots of resources. From figure 13 you can see the reported amounts of waste and how it has been handled. Landfilled ash and gypsum are excluded from this table.

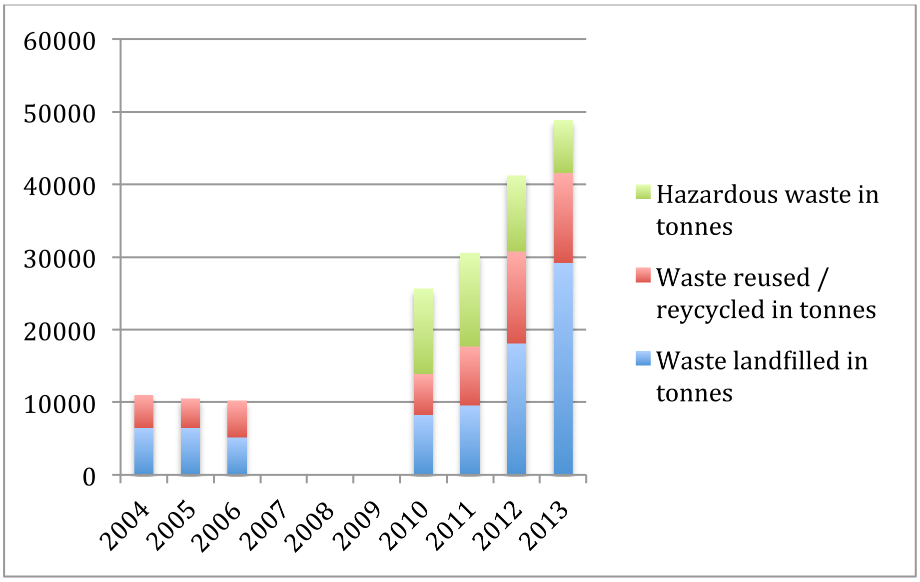

Figure 13. Fortum's handling of waste in tonnes 2004 – 2013

We can see that between 2004 and 2006 only information available was the waste landfilled or reused. From that information it is possible to calculate the utilization rate, which as an example was 49% in 2006 because 5,200 tonnes of waste was sent to landfill and the amount of waste recycled or reused was 5,000 tonnes.

After 2006 there was no information available until in 2010 Fortum published a sustainability report that included also the amounts of hazardous waste. There has been a clear increase of landfilled waste from 2010 that is mostly because of the cleanup of contaminated soils in the production areas. Fortunately the reuse of waste has increased that means the optimization of processes while the amounts of hazardous waste have decreased mostly because of new ways that were found to reuse hazardous wastes.

In 2010 the total amount of wastes generated totalled 25,600 tonnes that excluded gypsum and ash deposited to landfills because these are discussed in the part of industrial symbiosis in more detail. Of the total amount of waste 11,700 tonnes was hazardous, 8,300 was landfilled and 5,600 tonnes recycled. There also came a new Waste Tax Act in Finland that raised costs for waste and thus increased the pressure for utilization.

In 2011 the total amount of wastes generated totalled 30,500 tonnes that excluded gypsum and ash deposited to landfills. Of this 12,800 tonnes was hazardous, 9,600 was landfilled and 8,100 tonnes recycled. As an example from 2011, Fortum used 754,000 tonnes of waste-derived fuels in Sweden and Finland, even though recycled input materials accounted only for 2% of the energy content of Fortum's total fuel use. Also in Sweden 40,000 tonnes of waste was imported for energy production that is a good example of industrial symbiosis that needs a green supply chain to work in an environmentally friendly way.

Excluding the ash and gypsum sent to landfills Fortum's operations generated 41,200 tonnes of waste in 2012. Of this 18,100 tonnes was sent to landfill, 12,700 tonnes was recycled and 10,400 tonnes was hazardous. Actually for the first time about half of the hazardous waste was utilized as the rest was disposed securely. There was also first time some detailed information about the investments in waste management that totalled EUR 4.0 million of the total environment, health and safety operating costs that were EUR 62 million. I haven't examined the operating costs previously because the expenses and investments have not been completely uniform throughout Fortum and therefore the alignment of those investments would have been impossible.

The total volume of byproducts and wastes in 2013 was 1,025,000 tonnes that included ash and gypsum and the cleaning of contaminated soils and also some other desulphurization products. Of that, 863,00 tonnes was ash and 29,000 tonnes gypsum. The utilization percent of ash was 48% as the utilization percent of gypsum was 99%. The total amount of waste generated was 48,800 tonnes excluding gypsum and ash deposited in landfills. Of this 29,200 tonnes was sent to landfill, 12.4 tonnes was recycled or recovered and 7,200 tonnes was hazardous of which 2,000 tonnes was managed to recover. In the next figure 14 we can see how the R&D costs have developed during the research.

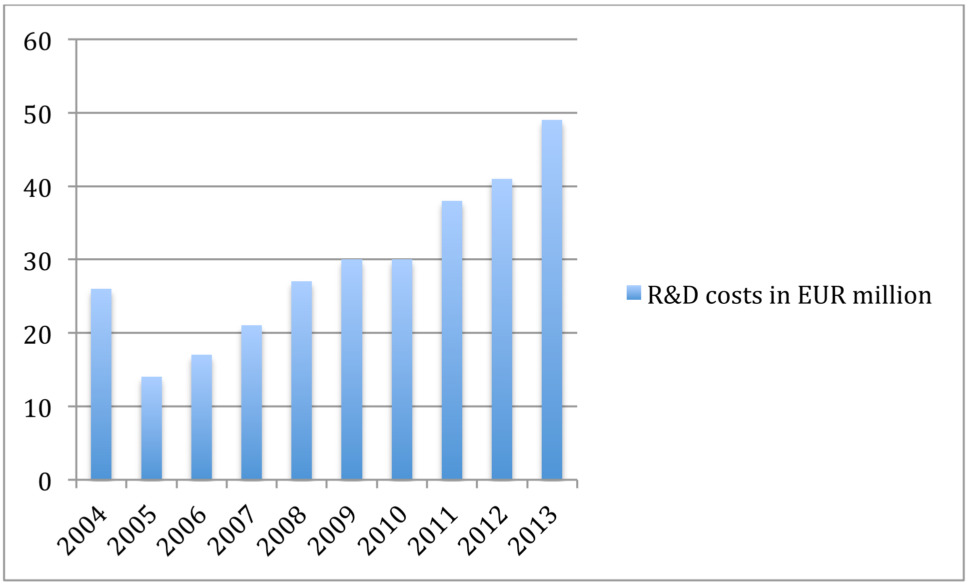

Figure 14. Fortum’s research and development costs 2004 – 2013

In figure **X** the big share of 2004 compared to 2005 was because of the separation of oil business in 2004 that still affected the costs. After that the expenditure of R&D has increased steadily even though most of the costs have been invested in the research of nuclear power and CHP. Other investments included for example solar energy, wave power and smart grids. Fortum’s long term goal was to be a completely carbon dioxide-free energy company and therefore company’s research & development activities have each year geared more and more towards that goal. In 2013 Fortum's R&D costs were increased to EUR 49 million even though this increase didn't mean much in terms of emissions if compared to the commenced use of natural gas in Russia in 2008.

In addition I have left out the environment, health and safety expenses because those were not completely uniform throughout Fortum and thus not reliable. Also the alignment of purely environmental expenses for each year was impossible, because environmental expenses are part of health and safety expenses in Fortum, which are not included in this research.

5.2.2 Industrial symbiosis

Ash from the incineration and gypsum from flue gas desulphurization have always accounted the biggest share of the byproducts and wastes from Fortum's energy production, over 90% on the average. Even though the share of waste-derived fuels of the whole energy consumption has only been between 1% and 3% during the research. In the following figure 15 you can see the ash and gypsum recycling rates that have been available.

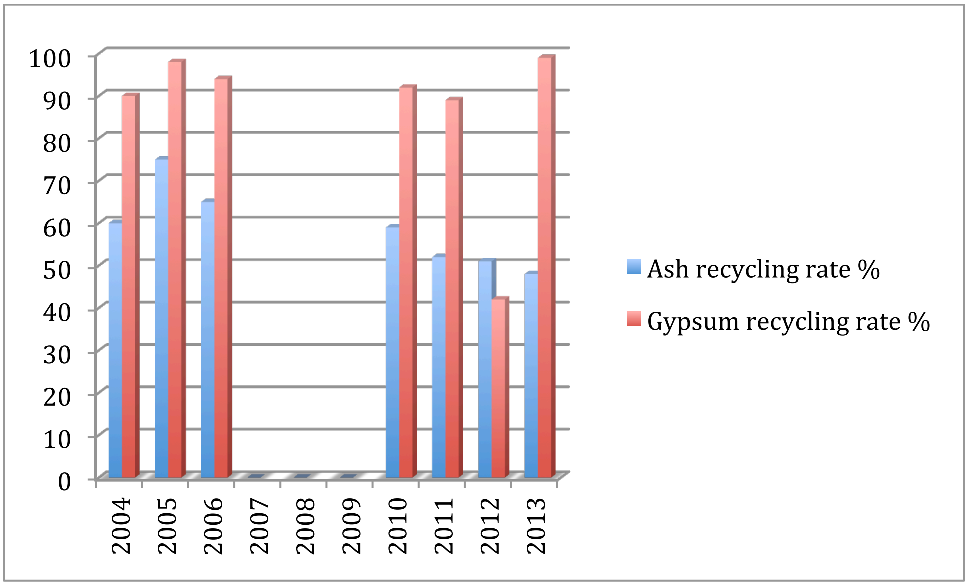

Figure 15. Fortum's recycling rates of ash and gypsum 2004 – 2013

From this figure 15 we can see that the recycling rate of gypsum has always been quite high even though the amount of gypsum generated has always been much lower than the amount of ash generated. Gypsum has been mostly used in the gypsum board industry as fly ash has been used for example in the construction industry. These are both good examples of industrial symbiosis. In 2012 the recycling rate of gypsum was exceptionally low because the reuse possibilities didn’t materialize that year. The recycling rate of ash has unfortunately decreased since 2006 mostly because in Russia ash was stored in basins because it didn’t have other usages and the handling was said to be difficult. One reason could also be the lack of research and development to find new ways to utilize ash more effectively.

Fortum commissioned two new CHP plants in 2010 that were in Poland and Estonia. Fortum also started to build a new waste-fired CHP unit in Sweden and another in Lithuania that were fuelled by municipal and industrial waste and therefore good examples of alternative fuels in the input side of symbiosis.

First time in 2010 Fortum had a sustainability report. Last time there was some info about waste management and by products in the annual report of 2006, but in 2010 it was more detailed and therefore I’m going to focus on that. Most of the waste generated by energy production consisted of various kinds of ash, bottom slag and gypsum created as a by-product of the desulphurization process. In 2010 about 803,000 tonnes of ash and 37,600 tonnes of gypsum was generated and compared to the previously reported amount of total waste the numbers are huge even though most is being used again. The recycling rate of ash was 59% and the recycling rate of gypsum was 92%. Of the ash about 36% was generated in Finland, 32% in Russia and 26% in Sweden. From other parts of Europe there wasn’t any detailed information, just said that waste and by-products were utilized and recycled as efficiently as possible.

The recycled gypsum goes to gypsum board industry and fly ash was used in the construction of material industry as made-up ground and in backfilling mines. New solutions were constantly developed for the utilization of ash and for example in Meri-Pori power plant it was further refined into ultrafine fly ash that can replace cement. These are good examples of the output side of symbiosis and how to find use for the wastes that were earlier dumped to landfills. Even though without greening the supply chain first the finding of these kinds of ways would have been difficult.

In the sustainability report of 2010 there was also information about Fortum's primary energy consumption for the first time that totalled 166 TWh. Of this 7 TWh was indirect energy consumption that included electricity, heat and steam acquired from elsewhere for the Fortum's own production. Indirect energy consumption is a good example of using symbiosis when the fuels are other firm's waste streams.

In 2011 the recycling rate of ash was 52% and the recycling rate of gypsum was 89%. In 2012 Fortum generated approximately 720,000 tonnes of ash and 19,000 tonnes of gypsum. The recycling rate of ash was 51% as the recycling rate of gypsum was 42%.

In 2013 Fortum produced energy in CHP plants in eight countries including four new CHP units in Finland, Sweden, Latvia and Lithuania that started production in 2013. The unit in Järvenpää, Finland used only biomass that was mostly forest chips or forest industry by-products like saw dust and bark that is typically harvested within 100km of the unit. It is a great example of industrial symbiosis and reduces CO_2 emissions of heat production in the area by 70% so the greening effects of supply chain are also significant. Another great example is in Lithuania where the Klaipeda unit was the first waste-fuelled power plant in Baltic countries and used municipal and industrial waste and biomass. It replaced old natural gas-fired capacity and reduced annual CO_2 emissions by 100,000 tonnes. Similar waste-derived CHP plant was opened in Brista, Sweden.

5.3 Kemira

In 2004 Kemira had four equally strong business areas that were pulp & paper chemicals, water treatment chemicals (Kemwater), industrial chemicals and paints. Group's net sales were EUR 1.7 billion and operating profit EUR 0.11 billion. The environmental data of Kemira was based on reports from 85 sites worldwide. In the last quarter of 2004, Kemira Grow How that was a part of Kemira listed as an independent company. As a consequence of this and other smaller divestments there was a huge decrease in Kemira's environmental loading resulting in significant improvements in reported amounts of environmental releases and waste & resource parameters. It should be noted that the divested businesses represented approximately two thirds of the annual production volumes. At the end of the research in 2013 Kemira repositioned the company to be a global chemicals company that served customers in water-intensive industries that were pulp & paper, oil & gas, mining and water treatment. Annual sales were EUR 2.2 billion as the operating profit was EUR 0.04 billion as seen from figure 16.

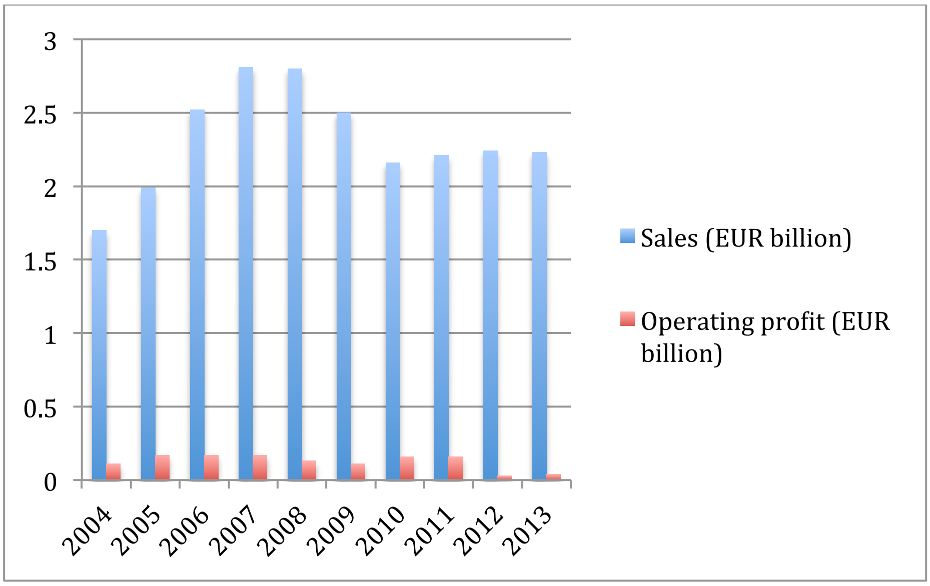

Figure 16. Kemira's sales and profits 2004 – 2013

After the seperation in the end of 2005, Kemira was employing 7670 people and had sales of EUR 2.0 billion and operating profit of EUR 0.17 billion. Kemira's sales rose 18% and operating profit was up 48% mainly because the acquisition of Finnish Chemicals by the Pulp & Paper Chemicals business and the acquisition of Verdugt within Performance Chemicals. Kemira also purchased Lanxess paper business for EUR 88 million that made Kemira the world-leading supplier of pulp and paper chemicals.

In 2006 Kemira created a concept that made it possible to manufacture major part of the coatings products on-site at the retail store primarily using only a few basic components. This was a good example of greening the supply chain because the concept reduced Kemira's shipments and retailers' need to keep large stocks.

In 2008 Kemira changed its strategy and started to focus on the water and fiber management chemistry that was divided into three segments: Paper, Water, and Oil & Mining. This was due to the development of new water treatment technologies that provided Kemira new opportunities and also because of the diverse water-related needs of customers. It also meant structural changes and therefore the Kemira Specialty business was discontinued and Tikkurila took over Paints and Coatings business. In 2008 Kemira was operating in 40 countries, had sales of EUR 2.8 billion and operating profit of EUR 0.13 billion. Because of the strategic decision to focus on its core business the importance of supply chain management increased. Therefore Kemira introduced its Supply Chain Management Unit in 2008 that increased quality, safety and especially purchasing power and cost efficiency. To reach these Kemira reduced the number of suppliers and harmonized sourcing and supply chain management processes.

In 2009 Kemira was still the world's leader in the supplying of coagulants in the water treatment business, where the increased demand and use of clean water facilitated municipal and industrial investments. In the paper industry water consumption of paper machines had decreased by one-third in the last 10 years because of the improved automation systems and more effective chemicals.

The most important thing for reporting was in 2012 when Kemira increased their transparency as they followed the Global Reporting Initiative's (GRI) G4 sustainability reporting guidelines for the first time and as one of the first companies in Finland. This was because of the stricter environmental regulations.

In 2013 Kemira had 4,453 employees, and operations in approximately 40 countries and sales to more than 120 countries. Alltogether Kemira had 650 raw material suppliers and 10,000 suppliers in total. To strengthen new strategy Kemira divested several of their non-core businesses that included Chemsolutions' fromic acid business, coagulants business in Brazil and their share in the Sachtleben joint venture. Nuclear power was still the most important CO_2 free energy source for Kemira. Kemira's by-products from production such as hydrogen as well as process heat and steam condensate were used for energy. The share of primary energy use was approximately 84% electricity and 16% steam and heat. Of the total energy use approximately 64% was carbon free.

5.3.1 Green supply chain management

Carbon dioxide emissions are important in the context of green supply chain. Kemira has reported these direct greenhouse gas emissions that came from the production every year during the research, and first time in 2013 it also had to report indirect and other indirect greenhouse gas emissions. These indirect emissions were huge compared to direct emissions, even though in the comparison of all these reports I'm going to use only the direct emissions because those were the only specified emissions available in the earlier reports as seen from figure 17.

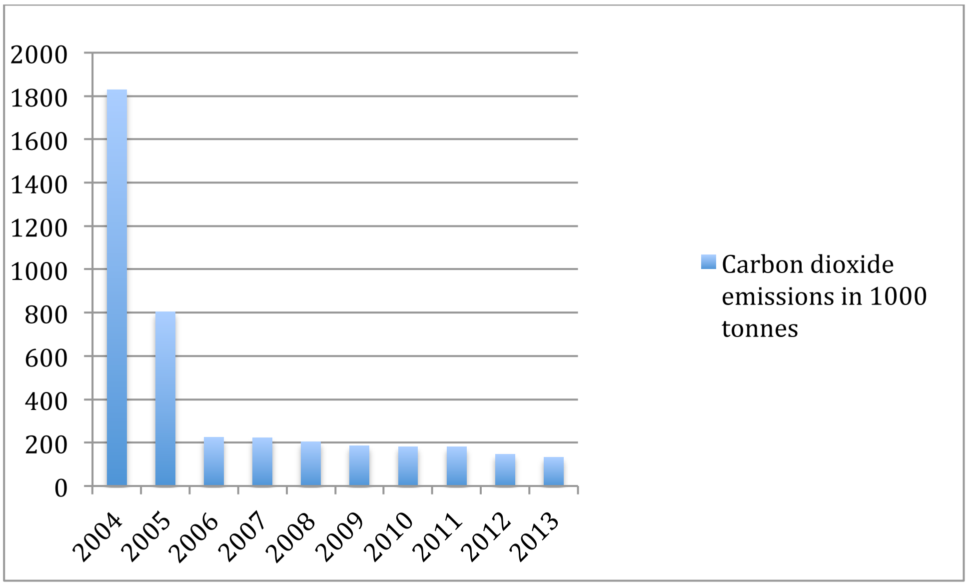

Figure 17. Kemira's CO_2 emissions in 1000 tonnes 2004 – 2013

The huge drop in figure 17 from 2004 to 2005 was because of the divested Grow How that still affected the statistics in 2005. After 2004 Kemira's carbon footprint has decreased substantially mainly because of the divestment, outsourcing of power generation and transition to generate electiricity with nuclear and hydropower.

In 2004 the total amount of greenhouse gas emissions would have been approximately 3,800,000 tonnes if Grow How had been included and calculated as CO_2 equivalents. But because the divestments still affected the total numbers, the announced exact share of carbon dioxide emissions was 1,828,000 tonnes that is more liable for the future comparison.

The total amount of carbon dioxide emissions dropped to 805,000 tonnes in 2005 mostly because of divestments and because Kemira doubled the amounts of purchased heat and electricity rather than consuming fuels itself for the production. This meant that Kemira's own fuel consumption lowered and emissions were more favorable because the indirect emissions from other companies were not obligatory to represent in 2005. Other greenhouse gas emissions were minor compared to carbon dioxide and therefore not necessary to present.

The earlier structural changes and the decrease of fuel consumption and increase of purchased electricity and heat resulted in lower emissions. Actually the amount of purchased heat was sixfold in 2006 compared to previous year. Therefore Kemira shifted its environmental focus towards closed manufacturing process monitoring, and more efficient recycling and waste management. The total amount of carbon dioxide emissions lowered to 224,000 tonnes and was the most relevant greenhouse gas.

In 2011 Kemira emphasized in its annual report that significant environmental impacts came from the production of raw materials and from the transportation by Kemira's suppliers and logistics service partners. This hadn't been discussed earlier in Kemira's reports and the answer was to focus on load optimization e.g. by sending full truckloads on the roads. They also calculated for the first time the specific CO_2 -emissions from transportations to be 26 kg CO_2 / tonne product transported, even though these amounts were minor compared to emissions from production. The total amount of CO_2 emissions was 163,000 tonnes in 2011.

The first report prepared according to GRI G4 guidelines was published in 2012 and used in the corporate responsibility report of 2013. I'm going to focus more closely on this new report as we can clearly see the actions taken for sustainability during 2012 and 2013. Therefore 2013 was also the first year that Kemira had a detailed summary of its greenhouse gas emissions**.** In 2013 the direct greenhouse gas emissions were 133,000 tonnes as the indirect emissions were 904,000 tonnes. Also other indirect greenhouse gas emissions were required to report according to GRI G4 guidelines that included emissions from Kemira's value chain and totalled 2,696,000 tonnes in 2013 and 2,677,000 tonnes in 2012. When all these are added together greenhouse gas emissions totalled 3,734,000 tonnes in 2013, and 3,774,000 tonnes in 2012. When the indirect emissions are compared to the amounts of direct emissions the difference is huge.

From figure 18 we can see how much the reported greenhouse gas emissions have increased after the inception of GRI G4 guidelines. The emissions are divided in to different scopes according to GRI G4 in which scope 1 represents direct emissions, scope 2 represents indirect emissions and scope 3 represents other indirect emissions.

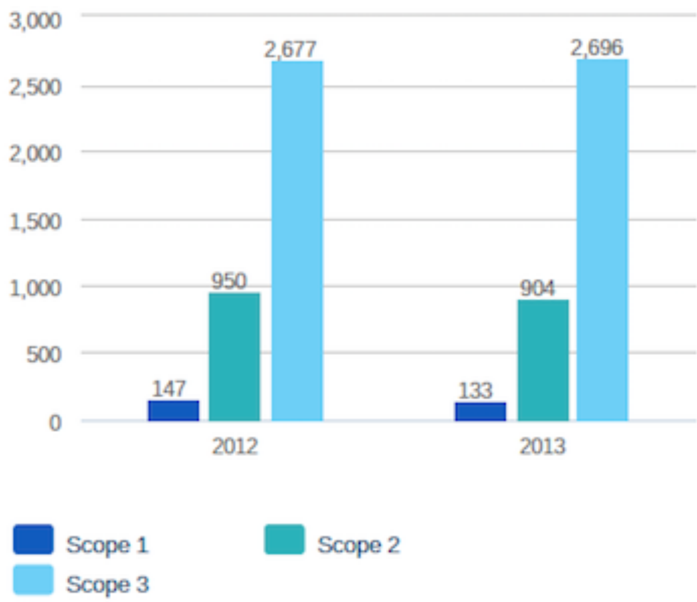

Figure 18. Kemira's greenhouse gas emissions 2012 – 2013 in 1,000 tonnes CO_2

In addition from figure 19 we can see how the other indirect (scope 3) emissions have divided in the value chain in 2013. Purchased goods and services pollute the most but it is also interesting to see that downstream and upstream flows have been divided separately and therefore are valuable information in the context of the future greening possibilities of the supply chain.

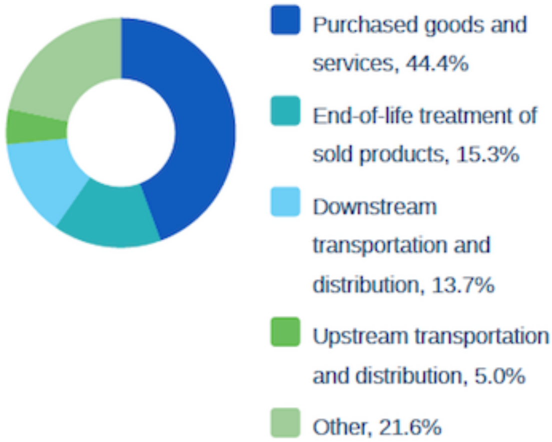

Figure 19. Kemira's largest greenhouse gas emissions in the value chain in 2013

The amounts of non-hazardous and hazardous wastes are also interesting in the context of greener supply chain and industrial symbiosis. From figure 20 we can see how these amounts have changed during the ten years.

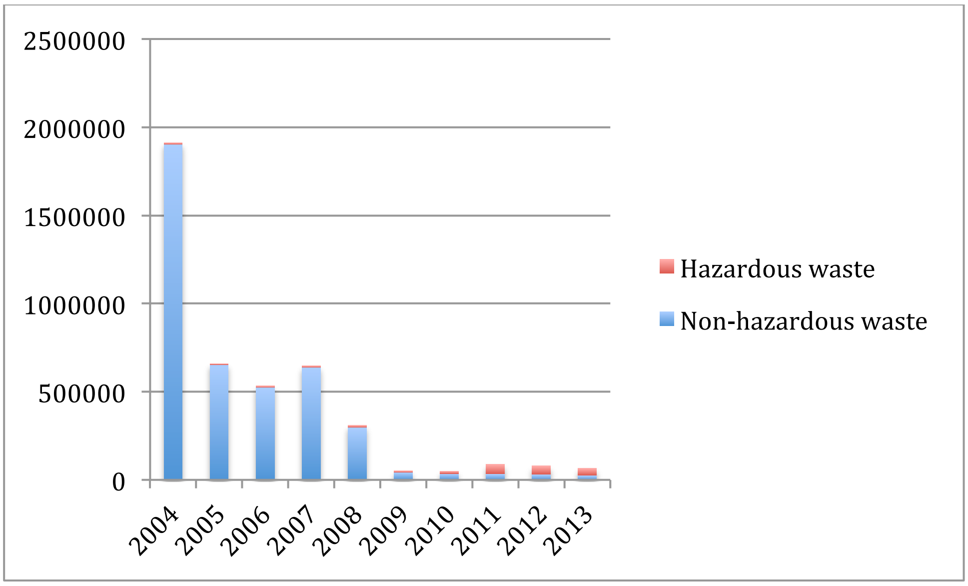

Figure 20. Kemira's hazardous and non-hazardous waste generation in tonnes 2004 – 2013

Concerning waste management, Kemira has reported the amounts of hazardous and non-hazardous waste. In 2004 non hazardous waste totalled as much as 1,903,000 tonnes because the calculations still included GrowHow as hazardous wastes totalled 10,310 tonnes. There wasn't any information about the end use of non hazardous wastes. From the hazardous waste 9% was recycled, 6% went to other unknown treatment, 13% was landfilled, 54% was incinerated on-site and rest off site. Incineration was a way to increase energy efficiency by burning wastes even though it does not replace the need for landfilling because it only reduces the amount to be landfilled and thus is not very effective way to capture the energy of wastes. Therefore research and development played a critical role in finding new ways to utilize wastes more effectively.

In 2005 the by-products of titanium-dioxide pigment production at Pori represented the only significant volumes of waste produced by the group. The total amount non hazardous waste was 654,000 tonnes as the amount of hazardous waste 5,290 tonnes. Of the hazardous waste 27% was now recycled, 24% went to other treatment, 16% to off-site landfilling, 23% to off-site incineration and rest 10% to on-site incineration. Clearly the amount of recycled waste had increased as the amount of incinerated waste decreased even though it was mostly because of the big divestment of Grow How.

After 2005 that the amounts stayed quite the same until 2008 when the iron sulfate piling area was closed in Pori. It was the single most important environmental remedial project taking years to accomplish and therefore also affected the statistics between 2007 and 2009.

In 2008 the amount non-hazardous waste was 299,000 tonnes as the amount of hazardous waste was 9,554 tonnes. Of the hazardous waste 27% was recycled, 19% went to other treatment, 25% to landfilling, 28% to off-site incineration and rest 1% to on-site incineration. There still wasn’t any information about the use of non-hazardous waste. In 2009 the amount of non-hazardous waste decreased by 80% to 44,000 tonnes mainly because of the closing of iron sulfate piling area in Pori. The amount of hazardous wastes was 7,109 tonnes of which 31% was recycled, 25% landfilled, 31% incinerated off-site, 1% incinerated on-site and rest 12% went to other treatment.

In 2010 the total amount of non-hazardous waste decreased to 26,000 tonnes as the amount of hazardous waste increased to 14,658 tonnes because of the remedial projects of contaminated soil. Because most of the hazardous waste was contaminated soil approximately 52% was landfilled, 13% was off-site incinerated, 17% was recycled and 18% went to other treatment.

In 2011 the amounts of hazardous wastes were suddenly bigger than the amounts of non-hazardous wastes. This was mostly because of contaminated land remediation projects at the sites that reflected to other off site treatment. It was also because of new GRI G3 sustainable reporting guidelines that was upgraded in 2013 to GRI G4 and restated the numbers of hazardous and non-hazardous wastes.

Because of the new sustainable reporting guidelines that came in 2011, Kemira had statistics of how much of materials purchased were classified as recycled materials. In 2011 the quantity of materials purchased was 3.65 million tonnes out of which 815 thousand tonnes (22% of total materials purchased) were classified as recycled materials from external partners. The amount of purchased packaging materials that were made of recyclable material was 13%.

In 2012 the quantity of materials purchased was 3.6 million tonnes out of which 938 thousand tonnes were classified as recycled materials from partners. Kemira also said to strive to reclaim plastic or other material used for packaging and thus minimizing the use of virgin materials but there wasn't any data about this expect some third party service that Kemira was using. Therefore this “greening” was an example of how to make the company look better with minimal actual change.

In 2013 Kemira also reported the materials used by weight or volume, which included the shares of renewable and recycled materials used. In 2013 Kemira purchased 3.9 million tonnes of material of which 23% was recycled or waste material from external partners as only 0.73% was renewable. Especially the share of renewable materials purchased was interesting in the context of symbiosis. In

2012 the share of recycled materials was 26% of 3.6 million tonnes of materials purchased, as the share of renewable materials was 0.83%. One major reason for the minor share of renewable materials was that nuclear power was the most important CO_2 free energy source for Kemira. From table 9 we can see the total weight of waste by type and disposal method according to G4-EN23.

Table 9. Kemira's total weight of waste by type and disposal method 2009 – 2013

G4-EN23: Total weight of waste by type and disposal method 1)					
Waste, tonnes	2013	2012	2011	2010	2009
Hazardous waste, total	41,096	48,436	55,305	14,658	7,109
Off-site landfill 2)	1,359	1,024	10,037	9,079	2,621
Off-site incineration	3,858	1,933*	2,343	2,357	3,271
Off-site recycling	3,032	2,652	2,145		
Other off-site treatment	32,818	42,826**	40,681**	3,164	1,217
On-site incineration	29	1	99		
On-site landfill	0	0	0	59	0
Non-hazardous wastes, total	25,192	31,024	33,394	35,500	44,000
Off-site landfill	13,432	11,107	12,238		
Off-site incineration	5,674	1,482	1,451		
Off-site recycling	4,406	14,286	14,866		
Other off-site treatment	1,580	1,691	2,617		
On-site incineration	30	21	25		
On-site landfill	70	2,437	2,197		
Total waste disposal	66,288	79,460	88,699	50,158	51,109

It consists of last 5 years waste disposals divided to hazardous and non-hazardous. The amounts of hazardous and non-hazardous wastes have been restated in the report of 2013 for all waste disposal methods in use at Kemira and therefore the numbers differ from the ones presented in the earlier reports according to new guidelines. The part that interests us is how much have the number of wastes in total decreased because when the wastes are decreased it could be a sign of more effective process or a sign of symbiosis because former waste could have been refined as fuel.

There has been a decrease every year in the total of non-hazardous waste even though the hazardous waste has increased every year. The huge rise in hazardous waste from 2010 to 2011 is according to Kemira mostly due to contaminated land remediation projects at the sites that reflect also to other off site treatment. According to Kemira it takes care of its environmental impact assessments and emission monitoring as defined by ISO 14001 and its own standards. But as we can conclude e.g. from the huge rise of hazardous waste generation, the perception of taking care of environment according to standards is extensive.

Kemira's environmental capital expenditure was an important part of greening the supply chain because it included for example environmental permit applications and other environmental investments and projects. Therefore it is interesting to look how it has developed during the ten years from figure 21:

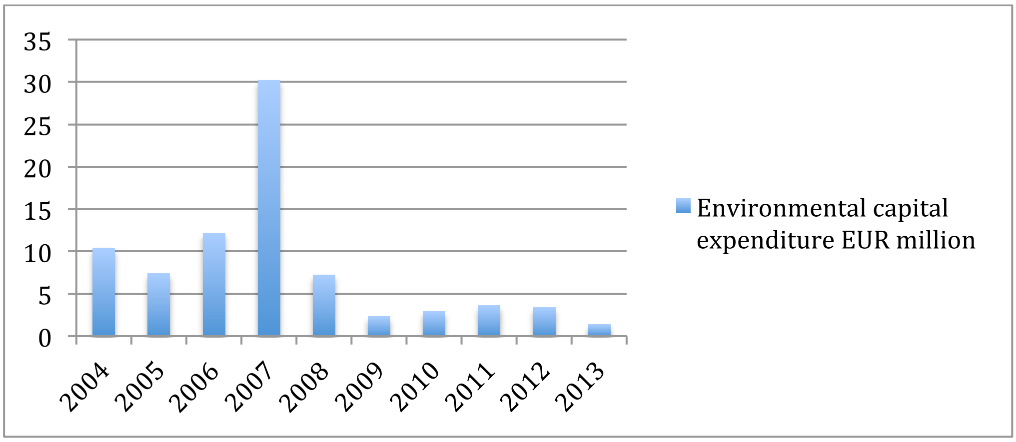

Figure 21. Kemira's environmental capital expenditure in EUR million 2004 – 2013

Kemira's environmental capital expenditure totalled EUR 10.3 million in 2004. Those expenditures included for example environmental permit applications and environmental projects, however none major investments were going on in 2004.

The environmental investments totalled EUR 12.2 million in 2006. Kemira also introduced its Code of Conduct in 2006 as a part of corporate responsibility. It was in line with the OECD guidelines for multinational enterprises and included economic responsibility, social responsibility and environmental responsibility.

Even though only 42 of Kemira's production sites had a certified Environment, Health, Safety and Quality (EHSQ) management system in place.

The huge rise of expenditures in 2007 was mostly because of the investments in byproduct management and productization at Pori's plant in Finland. Apart from that there hasn't been any major environmental investments, mostly because of the focus in structural changes. However the investments in environment are important and should be higher.

At the end of 2008, 66 sites had obtained ISO14001 certificates and no major environmental investments were under way because of the focus in structural changes. This was also seen as total environmental capital expenditure that decreased from previous years EUR 30.2 million to EUR 7.2 million in 2008.

In 2013 there was 75 sites that were certified with ISO 14001. The manufacturing sites represented 94% of Kemira's energy use that was 14,842 TJ in 2013. Since 2010 Kemira had made 388 improvement projects that had been completed in 26 sites and generated annually 174,000 MWh energy reductions meaning EUR 7 million cost savings in total. To succeed in cost savings follow up audits have been really important to gather information and generate a collection of best practices that will be used across the organization, even though the numbers are still small compared to total consumption.

Other statistcs that tell about the interest in environment and greening the supply chain are the amounts invested in research and development. The costs of research & development have developed as seen in figure 22**.**

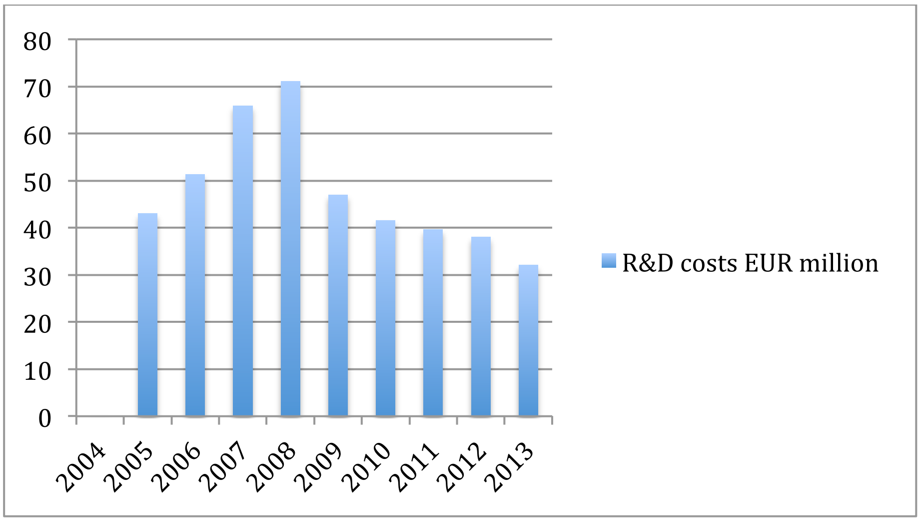

Figure 22. Kemira's research & development costs in EUR million 2004 – 2013

There wasn't any statistics about the R&D costs in the report of 2004. After that the amounts of investments increased until 2008 because of the new structural arrangements and new needs for environmentally benign processes. In 2008 R&D was also organized globally into five centers instead of previous 17 for more effective use as the total R&D expenditures amounted EUR 71.1 million. In 2009 the costs decreased because of the divestment of Kemira's Specialty business in 2008 that was fully reflected in the statistics of 2009.

In 2010 Kemira's products and applications enabled manufacturing processes to become less energy intensive through more efficient use and reuse of water. This was possible with the collaboration of Kemira's R&D, VTT and Center of Water Efficiency Excellence (SWEET). The research & development was focusing on three program areas that were water reuse, biomass utilization (produced through water purification and used as a source for energy production) and sustainable water chemistry. All the time more and more industrial by-products could be used as raw materials in Kemira's coagulant production, which reduced costs and helped rid the industry of unwanted production side streams. These are all good examples of greening the supply chain even though with the help of industrial symbiosis there might have been another company that could have utilized the unwanted side streams of Kemira with less investments.

The decrease of R&D investments after 2009 was because Kemira shifted its focus many times until in 2013 it repositioned to be a global chemicals company that served customers in water-intensive industries.

5.3.2 Industrial symbiosis

Kemira is unlike UPM or Fortum and thus the part of industrial symbiosis also differs. Kemira serves customers in water intensive industries and therefore it is important to see the percentages and total volume of water recycled and reused. This information was available for the first time in 2013 and can be seen from table 3.

Table 10. Kemira's percentages and total volume of water recycled and reused 2012 – 2013

G4-EN10: Percentage and total volume of water recycled and reused[1]		
$1000m^3$	2013	2012
Water recycled back in the same process	78	77
Water recycled in a different process, but within the same facility	58	128
Water reused in another facility	1,280	1,107
Total volume of water recycled and reused by the organization	1,422	1,312
Total volume of water recycled and reused as a percentage of the total water withdrawal reported under indicator G4-EN8	22%	20%

The total volume of water recycled and reused as a percentage was calculated from the total water withdrawal used as process water that was 6,341 (1000m3) in 2013 and 6,699 (1000m3) in 2012 according to G4-EN8. The percentages of the total recycled and reused water were quite good. The amount of water reused in another facility was a sign of symbiosis as the water reused inside the organization was a sign of optimization of processes.

In 2004 Kemira had a number of cooperation projects involving sludge-related problems both within sewage treatment plants and for the dewatering and disposal of sewage sludge. One good example was in Stockholm, where the Käppala sewage treatment plant was building the first full scale Kemicond plant with the objective of reducing the sludge volume by 50%, whilst improving the sludge quality for landscaping purposes. Also socially sensible energy efficiency was being achieved through projects aimed at building town waste incineration plants in the areas of Kemira's production facilities Oulu and Pori. For example power utility Oulun Energia was granted an environmental permit in summer 2004 for operating a waste-fired energy production plant that would be located in Kemira's plant area and also in Pori a heat utility had submitted a permit application for a waste co-incineration plant near Kemira's Pori facility.

Important acquisitions regarding symbiosis in 2006 were the acquisitions of water treatment chemicals business Cytec Industries Inc. (USA) and Galvatek (Finland), which were specialized in the treatment, recycling and recovery of industrial side streams. Therefore Kemira took charge of plants' operations related to the recovery and re-processing of industrial side streams, water treatment and sludge processing. Even though it was not Kemira's core business they saw a profitable business in that. Also its complete services enabled customers to recover and recycle precious materials, acids and bases back into their processes or convert them into commercial products.

An extremely good example of an industrial symbiosis that is based on local raw materials was in 2008 when Kemira introduced a new production process for calcium sulfate pigment, that is used as a coating and filler pigment for paper. It is energy efficient and consumes a third less energy than previous methods. That is because the raw material is calcium sulfate that Kemira receives from the Yara phosphoric acid plant located next to Kemira's Siilinjärvi plant, where it is generated as a by product in large quantities.

In 2009 Kemira strengthened its collaboration with Metso for high-quality paper products to be manufactured more cost effectively by synchronizing paper machine technology and the chemistry at the wet end of the machine. It was a good sign of industrial symbiosis. In 2010 Kemira launched a new program to identify energy-efficiency needs in its production plants. This program improved for example the using of waste heat for the preheating of another process. In Sweden the Käppala wastewater treatment plant was one of the most advanced wastewater treatment plants in the world as it served eleven municipalities in the Stockholm area and processed about 50 million cubic meters of wastewater every year. Also in China the enhancement of water chemical production in Tiancheng paper chemical plant was completed in 2010, which reduced emissions and waste.

From 2013 one good example of industrial symbiosis could be found from Joutseno, Finland. The production of district heating there is based on the utilization of heat from Kemira's manufacturing processes, and the combustion of hydrogen that is formed as a by-product. Formerly it was produced with natural gas that is a fossil fuel. It covers about 90% of the heating demands and saves 4,000 tons of CO_2 emissions and is therefore a good example of eco-industrial park.

From these examples we can see that Kemira has absorbed the use of industrial symbiosis. Even though for the symbiosis to work as effectively as possible it is important that each greenhouse gas of the whole process is calculated so that one company can't for example outsource or divest its energy production and thus lower its total greenhouse gas emissions only to look better for the investors. Therefore the integration of all parts is vital for the symbiosis to occur and to create win-win-win situations so that the environment is also considered responsibly in the total picture.

6. FINDINGS

The purpose of this thesis was to examine how the reporting of operations related to green supply chain management and industrial symbiosis has improved in UPM, Fortum and Kemira within the last ten years, with focus in the improved operations. The third research question was a result of analyzing the operations related to GSCM and IS in chosen industrial companies and concluding what possibilites could the combination of these two methods bring forth. Therefore I have divided findings in three different chapters based on the research questions and concluded the most important operations of each company.

6.1 Operations related to green supply chain management

Fortum's reporting related to operations in green supply chain management was consistent in 2004, 2005 and 2006 even though there wasn't that much information available if compared to 2010 when Fortum published its first sustainability report as a part of annual report. This was because of the new sustainability reporting guidelines (GRI) that were adopted fully in 2013. The sustainability report added for example the amounts of hazardous waste in the statistics of waste handling. Actually Fortum didn't report any statistics of the handling of wastes or byproducts from 2007, 2008 or 2009. This might have been because of the acquisition of Russian TGC-10 in 2008 that almost doubled Fortum's heat production capacity and increased power generation by 25%. This acquisition also increased the carbon dioxide emissions clearly because TGC-10 produced most of its energy with natural gas. Starting from 2011 Fortum had to report also the total greenhouse gas emissions according to sustainability reporting guidelines that included direct and indirect CO_2 emissions as well as other greenhouse gasses that were minor compared to carbon dioxide because Fortum is a producer of energy. Even though Fotum's production increased significantly, new ways were found to optimize processes and to reuse wastes more efficiently. Most of the R&D costs were invested in the research of nuclear power and combined heat and power plants.

Starting from 2012 also UPM had to report exact amounts of direct and indirect greenhouse gas emissions that were huge compared to the presented carbon dioxide emissions from paper mills' during the research time. Only significant rise in emissions was in 2011 when UPM bought paper mills with high shares of fossil fuels. The amount of waste sent to landfill has generally decreased during the research time because new ways were found to use wastes as resources rather than landfilled. There were only few exceptions in waste statitistics in 2006 and 2013 when the re-use possibilities for ash ceased.

Kemira's fuel consumption and emissions lowered drastically in 2005 when Grow How was divested and Kemira doubled the amounts of purchased heat and electricity rather than consuming fuels for the production itself. This meant that emission statistics were more favorable because the indirect emissions from other companies were not obligatory to present then. In 2012 Kemira published its first annual report accoding to GRI guidelines that included also indirect and other indirect emissions rather than reporting only the direct emissions, and the difference was huge. For example in 2013 direct greenhouse gas emissions were 133,000 tonnes as the total greenhouse emissions totalled 3,734,000 tonnes that included emissions also from Kemira's value chain. Kemira's reporting was consistent through researh time even though in 2011 it became more precise because of new GRI guidelines that were updated to G4 in 2013 as one of the first companies in Finland. This meant that Kemira had for example statistics of how much of materials purchased were classified as recycled materials. In 2013 Kemira also updated its total weight of waste by type and disposal method covering from 2009 to 2013 according to GRI G4.

6.2 Operations related to industrial symbiosis

In industrial symbiosis ash from the incineration and gypsum from flue gas desulphurization have always accounted the biggest shares of the byproducts and wastes from Fortum's energy production, over 90% on the average. Gypsum has been mostly used in the gypsum board industry as fly ash has been used for example in the construction industry and therefore the recycling rates are the statisctics that are interesting in the context of industrial symbiosis. As it was with the handling of other wastes and byproducts, there wasn't any information about the recycling rates in 2007, 2008 or 2009. The recycling rate of gypsum has stayed in approximately 90% as the recycling rate of ash has unfortunately decreased since 2006. This has been mostly because in Russia ash was stored in basins because it didn't have other usages and the handling was said to be difficult.

For UPM the most important indicator for industrial symbiosis was also the utilization rate of ash that was mostly utilized in earthwork operations outside factories in cement and brick industry depending on the country and its legislation practices. From 2004 there wasn't any information about the utilization rates because the ways to reduce waste volumes and to make use of waste were heavily under development. After that the utilization rates have been quite stable at approximately 90% even though from 2010, 2011 or 2013 I only found utilization rates of the total waste of which ash has the most significant proportion. Particularly in Finland ash has been used when company's old landfill sites were closed down and therefore the reuse of ash hasn't been sustainable in the context of symbiosis. However because the number of landfill sites to be closed down has decreased also the reuse of ash has decreased. That has forced UPM to increase co-operation with new partners to increase the reuse of ash in a sustainable way. It is a perfect example of industrial symbiosis because the flow of byproducts generated new relationships.

Kemira's business is unlike UPM or Fortum because it doesn't produce ash as byproduct and thus I have chosen to examine the percentages of total volume of water recycled and reused, because Kemira serves customers in water intensive industries. Actually this information was first time available in 2013 and the recycling rate was approximately 20%. Even though Kemira didn't have any comprehensive statistics of its operations related to industrial symbiosis it had many examples of different cooperation projects including effective use of symbiosis such as eco-industrial parks.

6.3 Possibilites of the combination of GSCM and IS

A deeper understanding and research in industrial symbiosis helps the understanding of green supply chains and vice versa. Often these operations were partially integrated together in annual reports which also made the coding challenging. The biggest challenge in the integration of these two operations was the effect that green supply chain management had on industrial symbiosis. The reason is that the quantity of the byproducts used in symbiosis is determined by the demand of the core product and thus without trust and cooperation among diverse partners the production levels of byproducts could be too low for reuse. Even though in most of the cases greening the supply chain was a prerequisite for the industrial symbiosis to occur, especially if the distances were longer than in eco-industrial park for example. Consequently industrial symbiosis is also more likely to occur when mutually beneficial relationships align the interests of all parties.

However a perfect symbiotic system between firms in which all wastes are internalized within the system and completely consumed is not known to exist. Thus most firms do not rely purely on symbiotic model, but a hybrid form that integrates forward and reverse supply chains with industrial symbiosis. An example of a hybrid supply chain is when wastes of one firm are used as inputs for another firm in exchange of money. This was the most common example found in this research that offers many possibilites. The recycling rate of ash is a good example because in that, ash is mostly used in operations related to industrial symbiosis outside the factory, and partially in operations related to green supply chain management inside organizations own operations. The opportunities that come from the flow of by-products are the ones that companies should give more attention to. Clearly most of the time research and development and environmental investments were focused to improve own operations rather than finding alternate ways from outside the organization to reuse the wastes more effectively and economically. Finding the right balance between green supply chain management and industrial symbiosis is where the possibilites lie in the combination of GSCM and IS.

7. CONCLUSIONS

The study indicates, that the environmental regulations and reporting standards have forced the studied companies to report their operations related to green supply chain management and industrial symbiosis more in detail during the last ten years. Reporting improved in each company at least by year 2013, mostly because of new sustainable reporting guidelines that were adopted. The operations related to green supply chain management in the studied companies are more common compared to operations related to industrial symbiosis. In addition, the adoption of green supply chain definitely supported the adoption of industrial symbiosis if the challenges were seriously taken into account.

High cost and uneconomical recycling were the most significant barriers in the transition towards greener supply chains. Fortunately management's views have changed with the help of environmental standards and it became clearer that green supply chain management and industrial symbiosis bring real benefits if used wisely. Even though the word ”green” was used too aften as a buzzword in annual reports just to make the companies look better with minimal effort. From table 11 you can see the answers to the first research question and from table 12 the answers to the second research question. These are also managerial implications because focusing on these issues will facilitate the managing of operations and networks in GSCM and IS.

Table 11. Improvement of reported operations related to GSCM

Supplier collaboration was made tighter
Green purchasing was highlighted. It was an important part of business and each company had their own code of conducts to pressure suppliers to take environmental actions during the process.
Parent companies guided suppliers to accredit to the environmental standard ISO 14001. This happened gradually because in 2004 there was basically no suppliers with ISO 14001 certification and in 2013 most of the suppliers in each company

had certifications.
Awareness seminars were held more often. These were important for suppliers and contractors to share the information of the benefits of cleaner production and technologies
Transparency was improved. From data gathered there was clear evidence that transparency brought efficiency and environmental benefits because information was widely available and everybody could use it. It also benefited the sharing of know-how.
Optimization of processes was made more efficient. It was the single most important process to reduce solid waste and emissions. Even with small modifications in processes companies saved huge amounts of money and reduced waste and emissions.
Increased amounts of combined heat and power plants that were important in the optimization of processes.
Clear movement towards environmentally friendly raw materials. Although the emission targets were hard to reach without a huge share of nuclear power.
Increased expenses in research and development that were essential for constant development.
Increased use of cleaner technology processes to make savings in energy, water and waste.
The reuse and recycle of waste was improved
The efficacy of transportation was enhanced.
Eco-labeling played a bigger role

Table 12. Improvement of reported operations related to IS

The use of residual resources and byproducts from other firms as feedstock increased. Although the share of these fuels was minor in each company compared to traditional ones because it was harder to innovate new possible waste based fuels from other firms than to invest in the output side because waste was generated in any case.

Increased amounts of new eco-industrial parks
The management of companies’ own residual resources and byproducts and the productive use of waste increased
New ways to generate symbiosis were innovated

The third research question was about the possibilities that the combination of GSCM and IS could bring forth. From the research can be concluded that industrial symbiosis offers opportunities that extend beyond pollution prevention and control, that for many companies are the first steps in the greening of the supply chain. However the greening of the supply chain facilitates the adaptation of industrial symbiosis because it prepares companies to understand the requirements of industrial symbiosis. Prerequisite for this to occur is that relationships align the interests of all parties so that mutual benefit is gained and the possibilites of the combination of GSCM and IS could be discovered. The opportunities that come from mutual benefit and the flow of by-products are the ones that companies should give more attention to. Clearly most of the time research and development and environmental investments were focused to improve own operations rather than finding alternative ways from outside the organization to reuse the wastes more effectively and economically. Even though if the cooperation among diverse partners isn’t deep enough, the effect of green supply chain management on industrial symbiosis could also be negative, because the core products determine the quantity of the byproducts used in symbiosis. Thus flexibility and trust among partners is essential in the development of these operations for the future possibilities.

7.1 Delimitations of the research and implications to theory

Each company and its suppliers gradually acquired environmental certifications, mostly because of the legislation and new emission targets, but also because with these certifications it was possible to portray the best possible image of the company. That is also the reason why annual reports and thus this research could be criticized in addition to the fact that both green supply chain management and industrial symbiosis are quite new streams of research. All the more so there is a future need for an extensive research in these issues.

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