OULU UNIVERSITY OF
APPLIED SCIENCES

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ASSESSMENT OF PACKAGING MATERIAL LIFE CYCLE

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Master's thesis

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Oulu University of Applied Sciences

ABSTRACT

Oulu University of Applied Sciences
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Nokia Siemens Networks believes that their packing materials used for standard product deliveries are environmentally friendly. They had an interest to verify this assumption by evaluating environmental impacts in more detail. The purpose of this Master's Thesis was to define and create a Life Cycle Assessment model for most commonly used packaging materials.

The packing materials used in China were evaluated. The kickoff meeting with suppliers was the starting point for data collection. After some iteration, a Life Cycle Assessment model was created and finalized with the SimaPro tool. The results were analyzed, documented and reviewed in the steering team. Due to the lack of detailed information, the total life cycle of the packing items from design to disposal was not covered by this study. The study does not bring up any major concerns but confirms the strategic choices to be on the right track.

As a conclusion, the packing materials used by Nokia Siemens Networks were confirmed to be environmentally friendly. The packing items did not include any banned substances. The LCA results and the impact on the packing designers' work was documented and communicated. The identified improvement proposals were put forth into the packaging design process. Results from different suppliers were found to be quite similar. There is always a possibility to find more sustainable packing methods. NSN continues to work in that area in the future, too, by regularly evaluating new materials and packing methods.

Keywords: Life Cycle Assessment, LCA, Product packing.

PREFACE

This Master’s Thesis has been carried out at Nokia Siemens Networks for the Global Product Packaging Platform team during May 2011 – February 2013. It has been an interesting and challenging journey to learn the assessment method of the packaging life cycle. During this study I have got very valuable knowledge and experience for my daily work as well.

I wish to express my gratitude to my lecturer Jukka Säkkinen and other steering team members Seppo Niemelä, Matti Laajaniemi, Topi Volkov, Heli Lauronen and Timo Junno, for their encouraging supervision.

I want to give my most sincere thanks to Seppo Niemelä for allowing me to write this study and for providing me honest and valuable comments during the thesis work. My special compliments go to Topi Volkov for providing me such a great support and help with the SimaPro tool related issues.

Oulu 6th March 2013

Pirjo Honkimo

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ABBREVIATIONS

AP	Acidification Potentials
BTS	Base Transceiver Station
CAD	Computer Aided Design
CAS	Chemical Abstracts Service
CFC	Chlorine-Fluorine-Carbon
CML	Classification method based on the method published by CML of the University of Leiden in October 1992
EC	European Commission
EPA	Environmental Protection Agency
EPE	Expanded polystyrene
EPP	Expanded polypropylene
EPS	Expanded polystyrene
ESD	Electrostatic discharge
Fefco	European Federation of Corrugated Board Manufacturers
GHG	Greenhouse Gas
GWP	Global Warming Potential
HCFC	Hydrochlorofluorocarbon
HTP	Human Toxicity Potentials
IPCC	Intergovernmental Panel on Climate Change

ISO	the International Organization for Standardization
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LNG	Liquefied natural gas
MDF	Material data form
NSN	Nokia Siemens Networks
ODP	Ozone Depletion Potential
Poka Yoke	Technology designed to prevent defects and equipment malfunction during manufacturing processes.
PPCG	Paper Packing Co-ordination Group
RAINS	Regional Air Pollution Information and Simulation
RoHS	Restriction of the use of certain Hazardous Substances in Electrical and Electronic Equipment
REACH	Registration, Evaluation, Authorisation and Restriction of Chemical substances
SW	Software
UNEP	United Nations environmental Programme
U.S.	United States
USES-LCA	The Uniform System for the Evaluation of Substances adapted for LCA purposes
WEEE	Waste Electrical and Electronic Equipment Directive

1 INTRODUCTION

Today environmental questions are playing a very important role in every business. It is regulated as authorities have set up regulations which are forcing them to reduce emissions, but it is also interesting to notice that environmental impacts are considered to be so important that several companies are making environmental analysis and sustainable decisions of their own accord.

The United Nations environmental Programme (UNEP) has defined three dimensions for sustainability as shown in figure 1: economic, social and environmental. Life Cycle Management is for organizations, which have expressed a wish to produce or trade products, which are as sustainable as feasible, to improve their public image, visibility, general relations with stakeholders, and increase their shareholder value, as well as, awareness of and preparedness for changing regulatory contexts. (United Nations Environment Programme, 2007).

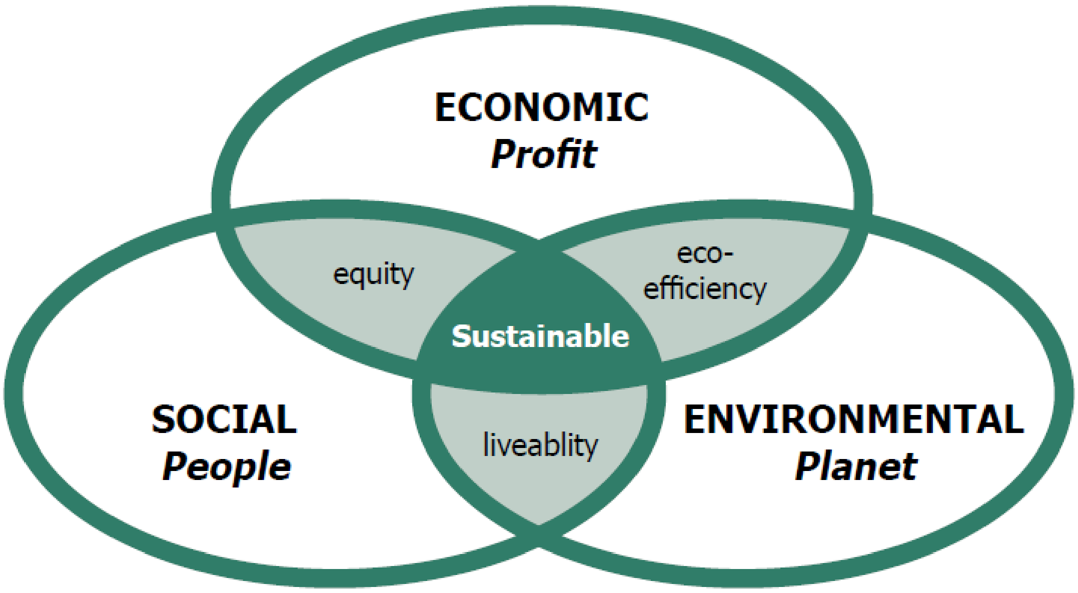

FIGURE 1. Dimensions of sustainability (The United Nations environmental Programme, 2007)

Under this approach, Life Cycle Assessment is a specific tool which is used to assess the environmental impacts of a product packing from design through production and use until disposal. It is useful to look at all dimensions having an impact to sustainability when making the analysis. One area might look good at a cost of another.

Life Cycle Assessment brings knowledge, which helps to integrate environmental affairs into packaging related decision making. The starting point for this Masters' thesis is to assume that the packing materials used by Nokia Siemens Networks are environmentally friendly. Some packing materials are assumed to be more environmentally friendly than others, and, thus, expectations are applied to the material selections.

Nokia Siemens Networks' mission is to grow our business sustainably. We will do that by behaving ethically and being responsible employers, by helping our suppliers and customers be more sustainable, and by working with wider stakeholders on global challenges facing the planet. (Nokia Siemens Network internet, about us/sustainability).

1.1 Background

The long standing interest of NSN in environmental questions is the main reason to execute a product packaging Life Cycle Assessment. The results will not be published as such. Only key findings are reported in this Masters' Thesis. The full details of the packing material LCA will be used only for the NSN internal purposes:

- To evaluate the environmental impacts of the NSN packaging.
- To identify opportunities to further reduce environmental impacts of the packing items.
- As input for packing designers to support sustainable material selections and design creation.
- To support long term strategic packing material selections.

1.2 Standards

Life Cycle Assessment technique has been developed to understand and address the importance of environmental protection, and the possible impacts associated with products. The Standard ISO 14040 defines the LCA principles and frame work and ISO 14044 details the requirements for conducting an LCA.

The ISO standard defines the following four phases for an LCA study (figure 2):

a) The goal and scope of the definition phase.
b) The inventory analysis phase.
c) The impact assessment phase.
d) The interpretation phase.

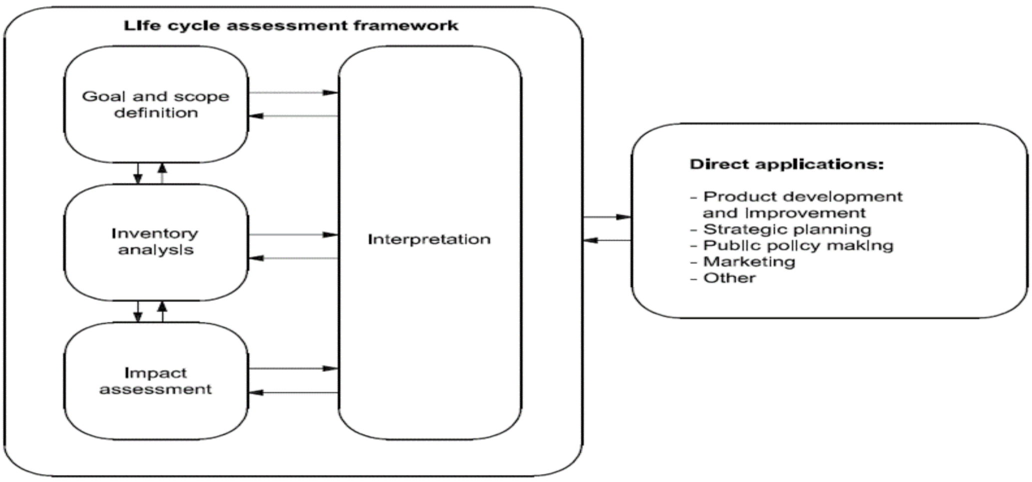

*FIGURE 2. Stages of LCA (*EN ISO 14040:2006*, 8)*

According to EN ISO 14040 a LCA can assist in:

- Identifying opportunities to improve the environmental performance of products at various points in their life cycle.
- Informing decision-makers in industry, government or non-government organizations (e.g. for the purpose of strategic planning, priority setting, product or process design or redesign).
- The selection of relevant indicators of environmental performance, including measurement techniques.

- Marketing (e.g. implementing an ecolabelling scheme, marking an environmental claim, or producing an environmental product declaration). (EN ISO 14040).

A target for product packing is to achieve maximum protection with a minimum packing material. Life cycle assessment is a systematic procedure to analyze product systems environmental impacts throughout its life time.

1.3 Governing legislation

Several legislations are governing packing in EU.

EU Waste Framework Directive 2008/98/EC

Directive 2008/98/EC sets the basic concepts and definitions related to waste management, such as definitions of waste, recycling, recovery. It explains when waste ceases to be waste and becomes a secondary raw material (so called end-of-waste criteria), and how to distinguish between waste and by-products. The Directive lays down some basic waste management principles: it requires that waste be managed without endangering human health and harming the environment, and in particular without risk to water, air, soil, plants or animals, without causing a nuisance through noise or odours, and without adversely affecting the countryside or places of special interest. (Directive 2008/98/EC).

European Commission legislation Packaging and Packaging Waste (94/62/EC)

This Directive aims to harmonise national measures in order to prevent or reduce the impact of packaging and packaging waste on the environment and to ensure the functioning of the Internal Market. It contains provisions on the prevention of packaging waste, on the re-use of packaging and on the recovery and recycling of packaging waste. This directive is for packaging materials while NSN products do follow RoHS and REACH requirements. (European Commission legislation Packaging and Packaging Waste (94/62/EC)).

Packaging must be assessed against at least one of the three recovery standards:

- Material recovery (EN13430:2004)
- Energy recovery (EN 13431:2004)
- Organic recovery (EN 13432:2000).

Packaging may be assessed against more than one of the recovery standards if appropriate.

SFS- EN 13430:2004 Packaging - Requirements for packaging recoverable by material recycling

Material recycling of used packaging is one of several recovery options in the post use strategy. In order to save resources and minimise waste, the whole system in which the packaging takes part should be optimised. This includes prevention as well as reuse and recovery of packaging waste. (SFS- EN 13430:2004 Packaging - Requirements for packaging recoverable by material recycling).

SFS- EN 13431:2004 Packaging - Requirements for packaging recoverable in the form of energy recovery, including specification of minimum inferior calorific value.

Since packaging waste used for energy recovery substitutes for other fuels, total system optimisation includes production of heat and/or power. This document defines and specifies the thermodynamic requirements for packaging to allow the incineration with energy recovery of packaging waste, but does not consider the transformation and use of the produced energy. Both packaging and recovery technologies are subject to continuous improvement. (SFS- EN 13431:2004 Packaging - Requirements for packaging recoverable in the form of energy recovery, including specification of minimum inferior calorific value).

Standard SFS- EN 13432 packaging recoverable through composting and biodegradation – Test scheme and evaluation criteria for the final acceptance of packaging

Organic recovery of packaging and packaging materials, which includes aerobic composting and anaerobic biogasification of packaging in municipal or industrial biological waste treatment facilities is an option for reducing and recycling packaging waste. Using these biological technologies, the aims of the Directive 94/62/EC of the European Parliament and of the Council on Packaging and Packaging Waste (Brussels 5 December 1994) in this respect can be met. (Standard SFS- EN 13432 packaging recoverable through composting and biodegradation – Test scheme and evaluation criteria for the final acceptance of packaging).

Landfill Directive 99/31/EC

Council Directive 99/31/EC of 26 April 1999 on the landfill of waste entered into force on 16th July 1999. The deadline for implementation of the legislation in the Member States was 16th July 2001."The objective of the Directive is to prevent or reduce as far as possible negative effects on the environment from the landfilling of waste, by introducing stringent technical requirements for waste and landfills. The Directive is intended to prevent or reduce the adverse effects of the landfill of waste on the environment, in particular on surface water, groundwater, soil, air and human health. (Landfill Directive 99/31/EC).

RoHS Directive 2002/95/EC

EU legislation is restricting the use of hazardous substances in electrical and electronic equipment. The objective of these schemes is to increase the recycling and/or re-use of such products. It also requires heavy metals such as lead, mercury, cadmium, and hexavalent chromium and flame retardants such as polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE) to be substituted by safer alternatives. (RoHS Directive 2002/95/EC).

REACH

REACH is the European Community Regulation on chemicals and their safe use (EC 1907/2006). It deals with the Registration, Evaluation, Authorisation and Restriction of Chemical substances. The law entered into force on 1 June 2007. The aim of REACH is to improve the protection of human health and the environment through the better and earlier identification of the intrinsic properties of chemical substances. At the same time, REACH aims to enhance innovation and competitiveness of the EU chemicals industry. The benefits of the REACH system will come gradually, as more and more substances are phased into REACH. (REACH).

Currently REACH does not have an impact on packing materials.

1.4 Environmental laws in China

All China laws and regulations referred in this chapter are based on IHS EIATRACK (Environmental Intelligence Analysis) English translations. Information and parts from EIA track Packaging and labelling in China report updated 29th January 2012 has been used.

The packing specifications measures in China are often recommendatory guidance documents only. Some instructions can be found in a standard, such as general rules of disposal and utilization (GB/T 16716.1-2008). It defines the generic guidance for packaging and utilization of packaging waste handling, which is not mandatory to be followed. The Chinese municipality's bans are often related to food packing and not directly applicable for the NSN packaging.

The Law of the People's Republic of China on the Promotion of Cleaner Production effective since 1st January 2003 defines the rules which are well in line with the NSN packing design principles:

- Consider the environmental impact of the packing while making the design.
- Use non harmful and less harmful materials.
- Products should be packed in a reasonably simple way in order to avoid over packing that hinders minimization of waste.

The circular of the General Office of the State Council on Controlling Over-packaging of Commodities 2009 defines regulations for consumer packing and is not as such valid for business to business packing. The Circular acknowledges that packaging for these commodities must satisfy basic functionalities such as protection, preservation, labelling, and decoration, but requires that these basic functionalities incorporate the principles of reducing volume, re-utilization, and converting wastes to resources. (The circular of the General Office of the State Council on Controlling Over-packaging of Commodities 2009).

The National Development and Reform Commission, report on Implementation of Report of the Standing Committee of the People's Congress on Clean Production Promotion Law Enforcement and
Review Opinion that the Regulations Restricting Over-Packaging of

Commodities and the Catalog of Packaging Subject to Mandatory Recycling are in the stage of completion and promulgation. This draft Regulations would prohibit the manufacture and sale of over-packaged products as well as design, manufacture and use of over-packaging. Over-packaging: Packaging of commodities should be reasonably simple. The draft regulations require that the packaging

- interspace ratio of the package of a commodity shall not be greater than 55%
- the layers of packaging shall not exceed 3
- the cost of packaging except for the original package shall not exceed 15% of the selling price of the commodity. (The National Development and Reform Commission, report 2010).

Separate actions from NSN would be needed if authorities provided similar requirements for packages of electronic product in the future.

No excessive packaging is allowed and requires that the product packaging shall be reasonable and ensure the materials, structure and cost of the packaging are appropriate in light of the quality, specifications and cost of the associated (packaged) products so as to reduce the generation of packaging waste. (Clean Production Promotion Law of China, 1 July 2012).

The NSN packing design rules support the waste reduction needs.

Enterprises engaging in the design of products, equipment, products and packages shall, in accordance with the requirement of reducing the consumption of resources and the generation of wastes, give preference to the materials which are recyclable, dismountable, degradable, innocuous, harmless or slightly harmful or poisonous, and the compulsory requirements in the relevant state standards shall be satisfied. Enterprises shall abide by the product packaging standards in the design of product packages so as to avoid resource waste and environmental pollution resulting from excessive packaging. (Article 19 of the Circular Economy Promotion Law of the People's Republic of China).

2 DEFINITION OF GOAL AND SCOPE

Life Cycle Assessment model is a simplification of reality and thus the results might be distorted in some way. The quantitative method has been used in order to develop the packaging LCA models in such a way that the simplifications and distortions do not influence the results too much. The packing item models are created based on the product specific substance data, which each packing material supplier has provided to NSN. The models already available in LCA tool, based on the European average data, have been used to compare the created packing material models. The purpose was to compare if the results based on the collected data are in line with the results of the existing models. Any big difference has been analysed by checking the data accuracy.

The person creating LCA also has a possibility to guide the results to the wanted direction. The modelling and selections has been done as objectively as possible. There was no advance pressure to end up to a certain environmental result and thus interference-free evaluation was possible.

The goal and scope related questions have been reviewed and agreed in the steering team before inventory analysis started.

2.1 Scope

Nokia Siemens Networks has created LCA for some BTS products including radio unit, system module and transport unit. Because of the continuation scope for the packing material, LCA was agreed to be packaging items related to the same products. Only the Chinese suppliers of packing materials agreed to be included in the scope.

The customer order content was agreed to be one RF module, one system module and one transport unit. Quite a large variety of different kind of packing items is included in the LCA scope (Table 1).

TABLE1. Packing materials in LCA scope

PACKING ITEMS IN SCOPE	PICTURE
Several different Fefco structure corrugated cardboard boxes with printing or perforation	
Heavy duty container, glued, stapled and printed.	
Molded EPE, EPP and EPS cushions	
Paper and plastic packaging tape	
Printed antistatic bag	
Plastic straps	
Desiccants controlling humidity (bentonite clay, activated clay, silica gel)	
Printed paper based identification sticker	
Plywood and metal pallet	
Air bubble film and wrap paper used to filling empty space inside a container (cushioning)	
Materials used for packing incoming material deliveries (pallet, paper, straps, plastic film etc) from the packaging material supplier to the NSN plant or Hub.	

The accurate bill of material from the NSN product data maintenance system was used. Additional packing item details have been collected from drawings (weight, material, printing, size etc). Bulk packing material such as tape, strap, and air bubble film etc usage has been collected from product specific packaging instructions and NSN generic unit packing instructions (container packaging).

Lifetime was defined to be one time use for all packing items. In reality, several items such as containers, pallets and kraft paper are reused several times before recycling. The only exception is the metal pallet which is modelled to be reused eight times before recycling. In real life there can be more reuse times since cleaning and repair are used.

There is a lot of ready modelled material data available in the LCA tool. It was decided to use more specific foreground data since it was already available. The Packaging and Packaging Waste Directive 94/62/EC amended with 2004/12/EC and REACH are followed in NSN. Based on these regulations NSN is requesting each packing vendor to fill in the Material Data Form. By providing the MDF, the vendor confirms that they fill in all needed regulations. These regulations set forth obligations to reduce over-packing, restrict dangerous material usage in packaging, increase packaging material recycling and reduce landfill etc.

Detailed substance data was collected into a Excel sheet for every packing item. Chinese suppliers have amended detailed information and confirmed the correctness of the data.

Only a selected end of life scenarios was included in the scope:

- 100% incinerations e.g. burned in open fire/utilized for energy creation by burning.
- 100% landfill

- 100% recycling. Material will be cleaned and processed to be used as a raw material for a new packing or other product. Landfill is also considered to be re-cycling.
- 70% incineration & 30% recycling
- 70% recycling & 30% incineration
- Reuse metal pallet eight (8) times for same (after removed used for different function)

2.2 Out of scope

The steering team has out scoped several questions mainly because the information is difficult to get or can be considered to be company confidential (Table 2).

TABLE 2. Packing materials out of LCA scope

Out of scope
Packaging documents like packing list, plastic document envelope etc.
Antennas, cables, batteries, rectifiers which are not included in BTS configuration and sold as a separate items.
Packing material production process and chemicals used in production (heat, steam, liquids,water etc).
Metal pallet repair and cleaning due to lack of information.
Supplier production energy use and waste statistics information.
Fuel consumption (coal, gas) used for electricity creation in China.
NSN internal energy usage since difficult to allocate for selected products only.
Supplier's raw material deliveries and 2nd tier supplier transportation information.
Machines and tools life time and other impacts needed in packing material production. Information is difficult to get and allocate for selected products only.
Machines and tools needed in actual product packing box sealer, vacuum lifter, fork lift, strapping machine, stapler, taper, hammer etc.
Moulds, printing plates and other tools supplier needs in packing item production.
1st and 2nd tier supplier raw material supply chain.
Originally LCA scope included an excel tool creation for NSN internal purposes.It was agreed later in steering team not to be needed and thus it has not been created. It can be created later if needed.

2.3 Boundaries

Life Cycle Assessment should cover every impact associated with all the stages of a process from cradle to grave. It includes a demand/supply chain from raw materials through materials processing, manufacturing, distribution (production plant/outbound hub), use phase, repair, maintenance, unit disposal or recycling. This packaging material LCA does not totally comply with this definition due to the lack of end-to-end information.

The supplier related questions are the main reasons limiting fulfillment of total cradle to grave view. The raw material sourcing and actual packing item manufacturing related items, as listed in 2.2, would have been needed for a total view. The areas where NSN has a possibility to impact are covered and evaluated in this LCA. NSN can impact on the supplier environmental questions by requesting a report of how green values are followed in all their activities and processes.

The following boundaries were set:

•Packing items, which are not NSN own design, are considered to be components (tape, strap, desiccant etc). Data related to these items is from Nokia Siemens Networks existing database.

•LCA tool ready assumptions and build in models can be used whenever exact information from supplier is not available.

•European average energy mix data in SimaPro tool for electricity was used for products made in China. Data is considered to give similar or better environmental impacts than actual China data would do.

•Impact of transportation process is used only for key items, which are needed for packaging of NSN own products (1st tier supplier to NSN). European data modeled in SimaPro tool has been used since accurate China data was not available.

2.4 Unit process

Packing material transportation from long distance is not at all environmentally friendly. Packing material requires a lot of cargo space and can also be very heavy (pallet, container). Due to the high volume of the packing materials needed it is ideal to produce them as close to the use location as possible. All products in this LCA scope are produced very close to use location in China. By doing this NSN has minimized environmental impacts caused by inbound transportation.

The first tier supplier of the packing material produces the packing item by themselves or is purchasing them from the second tier suppliers. 1st tier supplier delivers packing items to NSN production plant in Suzhou or Shanghai. The products are packaged into a unit package at the manufacturing plant and further delivered inside a container or on a pallet to Suzhou hub. A container is used for unit storing in a high collector storage until needed for a shipment.

The products needed in the BTS configuration are picked and packed against the customer order in the hub. The operators will select a suitable size container for each delivery in order to avoid “shipping too much of air”. The shipping company will pick up the delivery from the hub. The product configuration is on its way to the customer warehouse.

The installation persons unpack the unit at the customer’s warehouse or site. Waste collection and recycling points are arranged in a different manner in each country. All packing material waste is treated according to the country specific waste treatment instructions.

Figure 3 explains a complete unit process from the packing material vendor to the manufacturing plant and finally via the hub to the customer site in more detail.

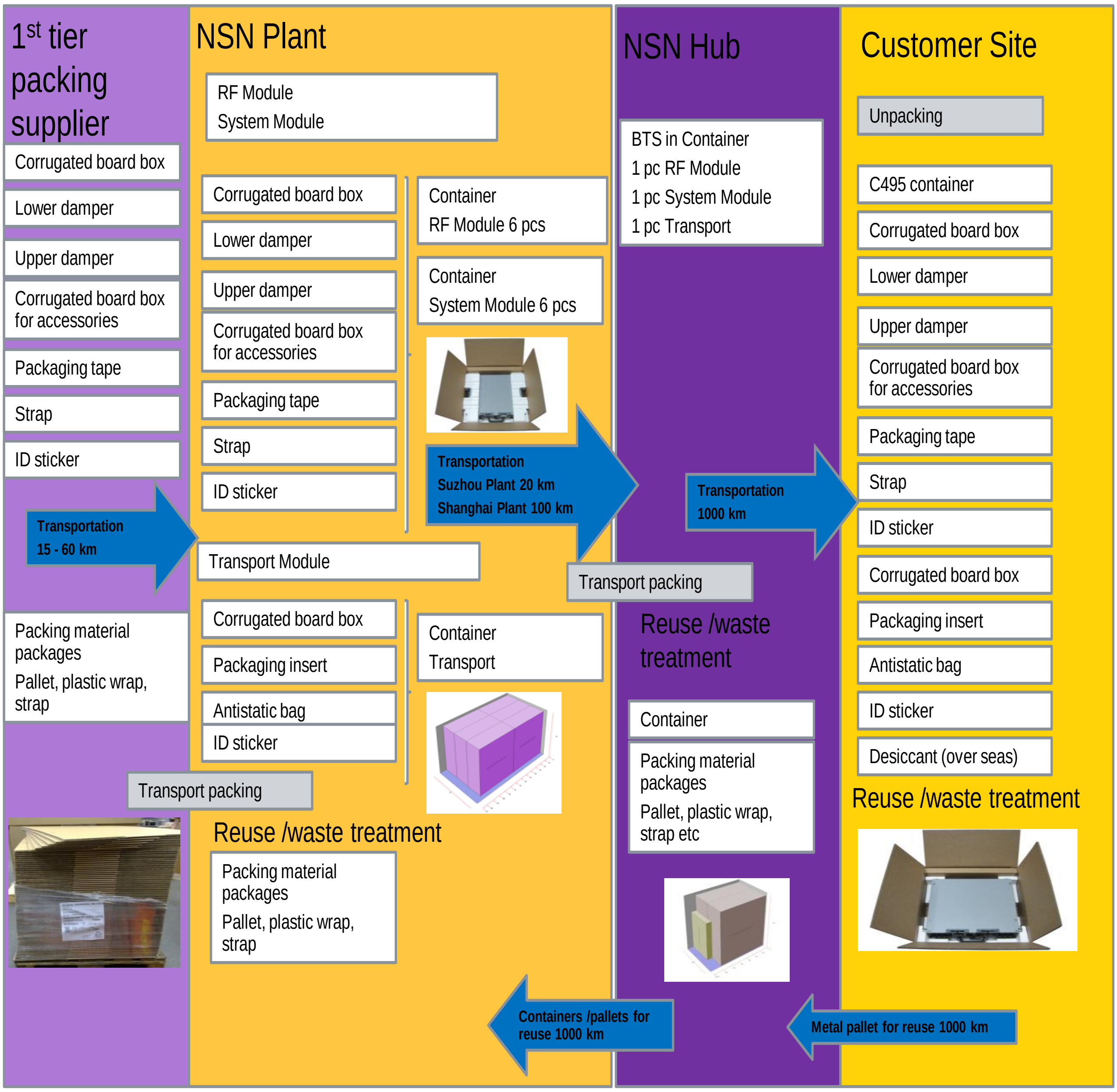

FIGURE 3. NSN packaging material unit process

The inventory analysis related questions have been reviewed and agreed in the steering team before the inventory analysis started.

3 INVENTORY ANALYSIS

The inventory analysis is the most time consuming part of the LCA work. It includes data collection and entry to the LCA tool.

3.1 Tool selection

There are several LCA software versions available in the market with a free demo version on the internet.

- SimaPro from PRé Consultants

  SimaPro provides a professional, all-in-one tool for Life Cycle Management. Based on these metrics, you can make solid decisions to positively change your product's lifecycle. SimaPro is the LCA software used by industry, consultancies, and research institutes in more than 80 countries. (PRé Consultants internet).

- Umberto from Ifu Hamburger

For internal or external environmental consultants or process engineers the software Umberto is an indispensable tool for life cycle analysis (LCA), energy management or process optimization. (Umberto internet).

- GaBi from PE International

  With GaBi we provide the market leading Life Cycle Assessment software for assessing the sustainability of your products and processes. (PE-International).

The ISO standards are defined in a quite vague language, which makes it difficult to see if an LCA has been made according to the standard. It is not possible to get an official accreditation stating that an LCA, an LCA methodology or LCA software such as SimaPro has been made according to the ISO standard. So, no software developer can claim that LCAs made with a certain software tool automatically conform to the standards. (Introduction to LCA with SimaPro, 10).

LCA SW licence fee can be quite high. Nokia Siemens Networks had valid user licence available for SimaPro software. It was selected and used in this packing LCA. Product LCA has been done earlier with this same SW. To use same tool for packing LCA was considered to be continuation for product LCA work. Results can be compared when parameters, format, presentation etc are same.

3.2 Data collection

The MDF received from the packing supplier lists the main material fractions and present substances down to a CAS number level. The CAS registry number is a unique identification for every chemical. The substances in MDF are always checked against the NSN substance list to ensure that the quantity of the restricted materials is not exceeded. The substance list includes all materials listed in RoHS II directive and REACH regulations.

Data collection was started by creating an excel sheet of needed information. The substance and weight data for each packing item was collected from MDF. Other details were available from drawings and packing instructions. The component data from the suppliers' data sheet has been used when needed.

The kick-off meeting was held with each supplier. After discussing LCA in general, data collection Excel was also reviewed. All suppliers checked the packing material data, made the needed changes and amended the missing information as requested.

Excel data was used to model inventory into SimaPro tool for each packing item. Substance name and CAS number was used to identify right substance in tool. In case substance or CAS was not found from SimaPro, Google search engine was used to find synonym, chemical formula or some other data helping to find correct or substitute substance.

While modelling substances to the LCA tool several errors were found from the material data. In such case supplier was requested to check and update MDF. Updated data form replaced earlier version and it was archived in NSN data base. As lessons learned, it is a good practice to review the validity of the CAS numbers and substance name in MDF. The situation was improved for the future cases. It was agreed that the packing designer will check the MDF data for a packaging item before it is used for mechanical material data creation (packaging item and supplier specific data sheet).

Some MDF had been created for material components only (Kraft liner, Test liner) or needed data was missing (glue, printing ink). The LCA model requires complete cardboard material and thus the MDF update was requested from suppliers. The updated data form replaced the earlier version and it was achieved in the NSN data base. As lessons learned, a more specific material data query is in use now.

Some substances were not available in SimaPro tool at all. In those cases substitute material was selected with similar chemical formula. Depending on the item, the error rate in these few cases is 0.01% – 5%.

Additional information provided by the vendors is included in LCA process or product stages. Information of transportation distance, size of a lorry used for transportation, how packing material are packed for transportation, how many items in one delivery lot is included in models.

Energy consumption figures were requested from suppliers but they did not provide them. Transportation, energy and waste treatment data is considered to be background data and thus ready SimaPro data was used. It is known what raw material each supplier is using (gas or coal) for electricity creation. Detailed consumption figures and use processes are not known.

There was no data available from packing material vendor production process and tools. The processes defined in SimaPro are used when applicable and available. SimaPro data is validated mainly in Europe only and thus not exactly right information for China products. It was considered to be more valid data than try to make own China related processes without having accurate data available. The same process was used for each vendor and thus it did not create additional differences.

3.3 Waste treatment

Referring to Järvi-Kääriäinen Terhen and Margareetta Ollila, the role of packing is both to secure the product from damages during the transportation and warehousing and to avert product waste. An entire production chain of a product must always be considered. In order to reduce the amount of generated waste and environmental impacts the whole system should be optimized. (Järvi-Kääriäinen, Terhen, Ollila Margareetta, 2007).

When a customer is unpacking a product, the packing item becomes waste. Normal waste treatments are reuse, recycle or landfill.

3.3.1 Reuse

Packing materials can be reused in the same or a similar function without reprocessing or remanufacturing. Often some minor treatments such as washing, repair, painting or removing labels are needed.

Waste legislation and policy of the EU Member States shall apply as a priority order the following waste management hierarchy. (EU Waste Framework Directive 2008/98/EC).

Reuse has high value in this directive (figure 4).

FIGURE 4. Waste management hierarchy (EU Waste Framework Directive 2008/98/EC)

Assumption in waste management hierarchy is challenged by the packaging industry. The environmental performance of different types of packaging can only be determined on a case by case basis. In such an evaluation, all aspects of the packaging and the required functions of that packaging should be weighed. The waste hierarchy, that is currently the cornerstone of EU environmental policy, leads to serious inconsistencies in the determination of the environmental impact. (FEFCO, 2003).

The above opinion is the leading theme of FEFCO – the European Federation of the Corrugated Board Manufacturers – and the Paper Packaging Co-ordination Group (PPCG).

Reusable packing can be any kind of box, pallet, rack, container, filling material etc. The packaging construction needs to be durable materials such as corrugated board, wood, plywood, metal or plastic. Reusable packing typically has to be designed to withstand the rough handling of a logistics chain. Packaged products have to be moved safely and efficiently through the whole supply chain. Reusable packaging requires a well organized supply chain with managed shipping and return loops. Additional activities like incoming inspection, repair and washing might be needed.

Within the NSN distribution process, a functioning return loop is missing preventing to take full benefit of reusable packing items. Only some trials, like metal pallet, have been done so far.

NSN is already reusing packing material for both environmental reasons and cost savings where possible. The basic principle is to avoid transportation solely because of reuse. The containers and pallets used for incoming materials are re-used in factories, hubs and repair operations for outbound deliveries. Packing material returns are arranged in such a way that additional transportation needs are minimized. Heavy duty corrugated board material container and pallets are reused around 3-5 times.

3.3.2 Recycling

Packaging can be assessed against standard SFS- EN 13430:2004 Packaging - Requirements for packaging recoverable by material recycling.

Recycling means reprocessing packing material waste into a new products or producing a new product from a recyclable material. Recycling is reducing virgin raw material consumption, energy usage, green house gas emissions and pollution (water pollution form landfill, air pollution from incineration). Recycling is essential part of waste reduction. NSN is using international recycling symbol for all packaging where materials are recyclable (figure 5).

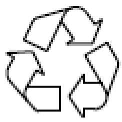

FIGURE 5. International recycling mark (NSN drawing)

There is an increasing need to identify products which can be recycled to be something new. Traditionally used paper is converted into new paper, used foamed polystyrene into new polystyrene, used plastic bottles to be raw material for straps etc. Recycling of plastic based packing materials is not easy, when compared with paper based packing materials. Recycling lessens the amount of property needed for landfill space. It also prevents the destruction of natural resources by reducing the need to use virgin materials, conserves natural resources like petroleum and reduces amounts of water from being used to mine, refine and manufacture products.

Recycling is reducing the amount of energy needed to make products when compared to making products from new materials. Energy savings can be seen as lesser greenhouse gas emissions (carbon dioxide CO2, methane CH4, ozone O3, nitrous oxide N2O, water vapour) associated with climate change.

NSN suppliers are stating usage of recycled materials in their production. Thus we know as a fact that recycling is reality but it was not possible to compare benefits of recycling to other waste treatment scenarios within this study. Detailed information was not available to create own model for recycling into SimaPro tool. Recycling is an empty process in SimaPro tool and thus modelling for NSN packing products could not be done. Benefit and costs in SimaPro is allocated for example to recycled cardboard.

Recycling of aluminium differs from other packing materials.

> Compared with the production of primary aluminium, recycling of aluminium products needs as little as 5% of the energy and emits only 5% of the greenhouse gas. The life cycle of an aluminium product is not the traditional cradle-to-grave sequence, but rather a renewable cradle-to-cradle. (World Aluminium, Global Aluminium Recycling 2009).

> There are no quality differences between a product entirely made of primary metal and a product made of recycled metal. Due to the overall limited availability of aluminium scrap, any attempt to increase the recycled content in one particular product would just result in decreasing the recycling content accordingly in another. It would also certainly result in inefficiency in the global optimisation of the scrap market, as well as wasting transportation energy. (Global Aluminium Recycling, p 15).

> The question of whether incineration or recycling is environmentally feasible can only be decided case-by-case, while comparing the specific alternatives by life cycle assessments, taking specific local circumstances and other aspects of sustainability into consideration (Global Aluminium Recycling, p 22).

3.4 Waste scenarios

The NSN product packing lifecycle ends at the customer site, where product is installed and taken into use. Packing has done its duty as product protection. Waste treatment at the customer site varies in different countries and re-use or re-cycling capabilities differs from country to country.

Different waste scenarios were included in to this LCA:

- Incineration 100 %
- Landfill 100%
- Recycling 30%/Incineration 70 %

- Recycling 70%/Incineration 30 %
- Recycling 100%.

3.4.1 Incineration

Packaging can be assessed against standard SFS- EN 13431:2004 Packaging - Requirements for packaging recoverable in the form of energy recovery, including specification of minimum inferior calorific value should be followed.

Incineration is a high temperature waste treatment and can be called also as a thermal treatment. It converts waste to fuel gas and heat, which can be used as energy. Incineration creates large quantities of leftover ash. Incineration is reducing waste volume very effectively. The NSN packing items should go to incineration when they cannot be recycled for quality reasons.

The EU Waste Framework Directive 2008/98/EC define incineration to be preferred waste treatment options over landfill. Clean packing material is good material for waste incineration plants. Sending packaging material for landfill should be avoided as it is seen as waste of resources.

3.4.2 Landfill

Packaging can be assessed against the standard SFS- EN 13432: Packaging recoverable through composting and biodegradation – Test scheme and evaluation criteria for the final acceptance of packaging.

Carbon dioxide (CO_2) and methane are two of the largest contributors to global warming among greenhouse gases. Landfill is one of the major sources for methane, which is a potent greenhouse gas. Due to anaerobic reactions landfill is causing global warming.

The amount of solid waste is significantly increasing and creating a need for additional space. There are problems associated with identifying new landfill sites, and space has high costs. New raw material must be harvested or mined to replace product if recyclables go to the landfill. Improving waste treatment will reduce amount of landfill.

EU has a Landfill Directive 99/31/EC, which directs to prevent or reduce as far as possible negative effects on the environment from the landfilling of waste, by introducing stringent technical requirements for waste and landfills. The Directive is intended to prevent or reduce the adverse effects of the landfill of waste on the environment, in particular on surface water, groundwater, soil, air and human health. In China and several other countries the legislation is not this powerful or is not available.

The NSN packaging consists of different components. Some materials are compostable, such as corrugated, and some other such as plastic is not, which means that packaging as a whole is not compostable. However, packing components can be easily separated by hand before disposal, the compostable components can be effectively considered and treated as such, once separated from the non compostable components.

Landfilling is always the least desired waste management option. Unfortunately in many countries landfilling is a predominant if not the only available municipal waste management option. Enormous efforts must be made all over the world, also in China, in order to change the situation and drastically reduce landfilling.

A “biodegradable” product has the ability to break down, safely and relatively quickly, by biological means, into the raw materials of nature and disappear into the environment. These products can be solids biodegrading into the soil (which we also refer to as compostable), or liquids biodegrading into water. Biodegradable plastic is intended to break up when exposed to microorganisms (a natural ingredient such as cornstarch or vegetable oil is added to achieve this result). Sustainable disposal of any product requires that its wastes return to the earth and are able to biodegrade. Nature biodegrades everything it makes back into basic building blocks, so that new living things can be made from the old. Every resource made by nature returns to nature - plants and animals biodegrade, even raw crude oil will degrade when exposed to water, air and the necessary salts. (Green goods, 2012).

4 ASSESSMENT OF IMPACT

Now that the packing material assembly and waste scenarios are defined the impacts can be analysed. SimaPro was used to calculate the Life Cycle Inventory results. LCI is a list of all raw material extractions and emissions that occur in the production of the assembly and the materials and processes linked to it. Some impact categories are dominated by production, while the end of life is dominating some others.

There is no reason to question the SimaPro calculation methods and thus they have been used. The background information has been documented on the system description page within the SimaPro tool. It has a history how the model was built and where the data has been collected. SimaPro database of packing material LCA is archived on the NSN server. It can be used for further analysis if needed. This is important if someone will combine product and packing into one LCA.

The impact assessment results have been reviewed and agreed in the steering team before interpretation started. All impact figures seen in the NSN analysis are low and do not cause any reason to make changes in the existing packing materials used.

The basic structure of impact assessment method used in SimaPro is characterisation and normalisation.

In **Characterisation** all the substances are multiplied by a factor which reflects their relative contribution to the environmental impact. (SimaPro 7, LCA Methodology).

The substances that contribute to an impact category are multiplied with a characterisation factor that expresses the relative contribution of the substance. For example, the characterisation factor for CO2 in the impact category Climate change can be equal to 1, while the characterisation factor of methane can be 21. This means the release of 1 kg methane causes the same amount of climate change as 21 kg CO2. The total result is expressed as impact category indicators" (SimaPro 7 Introduction into LCA, 29).

In **Normalisation** the quantified impact is compared to a certain reference value, for example the average environmental impact of a European citizen in one year” (SimaPro 7, LCA Methodology).

Normalisation is a procedure needed to show to what extent an impact category has a significant contribution to the overall environmental problem. This is done by dividing the impact category indicators by a “Normal” value. There are different ways to determine the “Normal” value. The most common procedure is to determine the impact category indicators for a region during a year and, if desired, divide this result by the number of inhabitants in that area. (SimaPro 7 Introduction into LCA, 31).

Many methods allow the impact category indicator results to be compared by a reference (or normal) value. This means, the impact category is divided by the reference. A commonly used reference is the average yearly environmental load in a country or continent, divided by the number of inhabitants. However, the reference may be chosen freely. You could also choose the environmental load of lighting a 60W bulb for one hour, 100 km of transport by car or 1 litre of milk. This can be useful to communicate the results to non LCA experts, as you benchmark your own LCA against something everybody can imagine. In SimaPro, there are often alternative normalisation sets available. After normalisation the impact category indicators all get the same unit, which makes it easier to compare them. (SimaPro7 Database manual, 2008).

Instead or looking results only, different materials environmental load has been compared to driving 1000 km with a passenger car.

Normalisation serves two purposes:

1. Impact categories that contribute only a small amount compared to other impact categories can be left out of consideration, thus reducing the number of issues that need to be evaluated.

2. The normalised results show the order of magnitude of the environmental problems generated by the product’s life cycle, compared to the total environmental loads in Europe. (SimaPro7 Database manual, 2008).

CML method is based on SimaPro classification method defined by R. Heijungs in NOH report 9266 at the University of Leiden in 1992. Impact analysis CML method in SimaPro tool combines emissions under categories. (SimaPro7 Database manual, 2008).

CML method was used also for NSN products LCA.

A SimaPro impact analysis result is calculating following effects. (SimaPro7 Database manual, 2008).

Greenhouse effect

The Global Warming Potential (GWP) is the potential contribution of a substance to the greenhouse effect. This value has been calculated for a number of substances over periods of 20, 100 and 500 years because it is clear that certain substances gradually decompose and will become inactive in the long run. For the CML 92 method, we have taken the GWP over a 100-year period because this is the most common choice.

Depletion of abiotic resources

This impact category is concerned with protection of human welfare, human health and ecosystem health. This impact category indictor is related to extraction of minerals and fossil fuels due to inputs in the system. The Abiotic Depletion Factor (ADF) is determined for each extraction of minerals and fossil fuels (kg antimony equivalents/kg extraction) based on concentration reserves and rate of deaccumulation. The geographic scope of this indicator is at global scale.

Acidification

Acidifying substances cause a wide range of impacts on soil, groundwater, surface water, organisms, ecosystems and materials (buildings). Acidification Potentials (AP) for emissions to air are calculated with the adapted RAINS 10 model, describing the fate and deposition of acidifying substances. AP is expressed as kg SO2 equivalents/ kg emission.
“The Regional Air Pollution Information and Simulation (RAINS) model is a European-scale integrated assessment model dealing with air quality and associated effects” (An Overview of the RAINS Model, Environmental Research Centre Report, 2006).

Eutrophication

Eutrophication is seen in the Globe report particularly as the problem of excessive use of fertilisers by agriculture, as a result of which nitrates leach out and poison groundwater supplies. In the CML classification Eutrophication refers mainly to air and water emissions. These rarely contribute more than 10% of the amount of fertiliser applied by farmers. In uncultivated biotopes, that are low in nutrients, however, this eutrophication can have a serious adverse effect on biodiversity.

In describing the level of eutrophication in rivers and lakes it is estimated that the critical value for phosphates is 0.15 mg/l and for nitrates 2.2 mg/l. At these levels there are no problems with eutrophication.

Ozone layer depletion

Ozone Depletion Potential (ODP) values have been established mainly for hydrocarbons containing combined bromine, fluorine and chlorine, or CFCs. Here too, one of the substances (CFC-11 also known as trichlorofluoromethane) has been adopted as a reference. As for the greenhouse effect, we have added values for CFC (hard) and CFC (soft). The ODP equivalents for these groups are again those of CFC-12 and HCFC-22 respectively.

Climate change

Climate change can result in adverse effects upon the ecosystem health, human health and material welfare. Climate change is related to emissions of greenhouse gases to air. The characterisation model as developed by the Intergovernmental Panel on Climate Change (IPCC) is selected for development of characterisation factors. The factors are expressed as Global Warming Potential for time horizon 100 years (GWP100), in kg carbon dioxide/kg emission.

Greenhouse gas emissions are defined as the total mass of a GHG released to the atmosphere over a specified period of time. Each gas has a different global warming potential (GWP). The GWP of a given GHG is calculated by multiplying the 'radiative forcing' impact of one mass-based unit (e.g. a tonne) of this gas relative to an equivalent unit of carbon dioxide over a given period. GHG emissions tend to be reported in carbon dioxide equivalents (CO2e), which are calculated by multiplying the mass of a given GHG by its GWP. CO2e is a unit used for comparing the radiative forcing of a GHG to that of carbon dioxide. (McKinnon Alan, Browne Michael, Whiteing Anthony, 2012, 35).

Human toxicity

This category concerns effects of toxic substances on the human environment. Health risks of exposure in the working environment are not included. Characterisation factors, Human Toxicity Potentials (HTP), are calculated with USES-LCA, describing fate, exposure and effects of toxic substances for an infinite time horizon. For each toxic substance HTP’s are expressed as 1,4-dichlorobenzene equivalents/ kg emission. The geographic scope of this indicator determines on the fate of a substance and can vary between local and global scale.

5 INTERPRETATION

Based on this Life Cycle Assessment, the environmental impact of NSN packaging can be considered to be low. Delivery quantities are big and it is important to use non-harmful and environmental friendly packing materials. NSN has continuous material data follow up in place and thus no harmful or restricted materials are used.

5.1 EPS, EPE and EPP cushions

The life cycle assessment was done for each cushion material type used by NSN (EPS, EPE, and EPP) separately. Based on the material data information from the suppliers' cushions do not include any banned substances. Abiotic depletion is the biggest environmental impact caused by the use of fossil fuel as a raw material. Carbon footprint, energy consumption and green house gas effects are visible in the analysis.

The cushion production process is not evaluated in this assessment. It is not assumed to include any restricted materials. Mould is made of aluminium, which can be reused. Pentane gas is used as the blowing agent during EPS production.

Pentane is more environmental friendly and causing less fluorinated greenhouse gases (F-gases) than 1,1,1,2-Tetrafluoroethane HFC-134a (Ympäristöministeriö, 2012).

EPS is expanded to the final shape by hot steam (water vapour). EPP and EPE are pre-expanded with heat and vacuum. At the end of the process the cushions are dried and packed for delivery.

EPS can be re-used as material (insulating material, soil improvement, drain pipe etc) or energy. EPE and EPP can be reused as energy at end-of-life. Plastics have a good heating value.

EPS has a bigger environmental impact than EPE or EPP. China is going to ban EPS in some time frame even though the schedule is still open. NSN is not using EPS any more for any new cushion designs. The decision is proven to be correct by this analysis as well.

Color is an additional material component in cushions as well as in some other packing items. Designer should define the color for cushion in a drawing only when it has a specific meaning. It can be used as an indicator, for example pink as dissipative material, white or black as an indicator for non ESD material. A colour already used by the supplier in volume should be considered as the first selection. The same production pipe is used for different colors. Changing colours between manufacturing batches needs pipe cleaning which has environmental impact caused by sewage disposal cleaning. Changing colours can cause visual defects in the end-product as shown figure 6. The volume color is black and thus a white production lot can have black spots. This visual defect does not limit the usage of the cushion. There is no data available to visualize impacts in figures or more details.

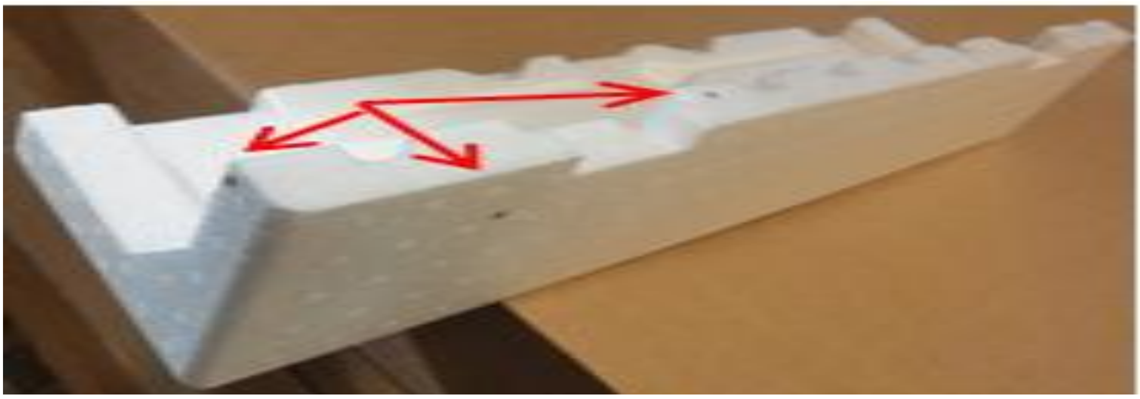

FIGURE 6. Visual defect in cushion

Landfill is not a preferred waste treatment for EPS, EPE and EPP. These materials are not biodegradable and require a lot of landfill space. It takes several decades to hundreds of years to deteriorate in the environment or in a landfill. As a litter these material can cause marine pollution and adverse effect on wild-life.

Based on the current EU classifications and the current draft of the risk assessment report, styrene monomer is considered to have low oral toxicity, and is not classified in terms of carcinogenicity or mutagenicity. However in common with many organic solvents, there are regulations setting inhalation exposure limits for people working with styrene monomer. (Styrene forum).

Processes and transportation has bigger environmental impact than materials. Manufacturing of cushions is ideal to be as close to use location as possible. Cushions require a lot of space and thus minimization of transportation need is environmental friendly choice. Crude oil price dictates plastics prices. It has direct impact to plastic cushion pricing as well as transportation cost.

5.2 Paper based corrugated board material

Life cycle assessment included NSN corrugated board boxes and containers. Based on material data information from suppliers corrugated board material do not include any banned substances. Paper layers are held together with adhesive made of starch which is from vegetable source. Ideally total lifecycle for corrugated board material would include everything from fibre production until it is recycled several times and finally becomes a waste. Analysis in this thesis was not this total since detailed data of manufacturing was not available from suppliers.

Abiotic depletion is biggest environmental impact caused by the use of renewable wood pulp as a raw material. Cardboard is one of the most recycled materials worldwide. Corrugated board materials are biodegradable and they require a lot of landfill space. It is waste of money to send cardboard box to a landfill.

When biodegradable products are exposed to nature, including oxygen and moisture, they break down relatively efficiently. Cardboard (unwaxed) 3 months is an example of how long biodegradable items take to break down naturally (assuming an adequate supply of oxygen and moisture). (Ecolife, 2011).

Corrugated board can contain some very small amount of lead. This is because re-cycled corrugated board material is often printed with ink including lead and due to the cumulative air pollution from the air. Lead in packaging or packaging components shall not exceed 0.01% by weight. There is almost always some printing in the box for example recycling mark is mandatory. Lead can be avoided if perforation is used for marking. Perforation is a set of holes creating needed marking. Puncturing requires machinery availability and capability varies between suppliers and design. Perforation technique cannot be used for all packing items.

Weight of packing is increasing transportation impact, which in turn is causing environmental issues in addition to issues caused by distance. Lighter the better is rule of thumb for all packing items in this sense. Current NSN container design includes separate inner and outer part. Total weight could be reduced by combining two parts to be one box. Less material means less waste. One package has also smaller process and energy impact than two piece packing item. This is only one view to design while re-use possibilities are other. Two piece structures allow the outer box to be changed while the inner box reuse continues.

The main waste stream of corrugated board is paper/board, which is recyclable. NSN is re-using containers several times for inbound deliveries from plant to hub and repair centres to distribution centres. Two piece container structures allow the outer box to be replaced if dirty or damaged, while the inner part usage can continue longer.

Recycling paper not only saves energy but also saves trees, reducing the amount of carbon dioxide present in the atmosphere. The EPA estimates that producing a recycled paper product requires only 60 percent of the energy required to create one from fresh wood pulp, and the Energy Administration Information reports that recycling a ton of paper can save 17 trees. Recycling paper also requires about half the water normally used in processing paper from virgin wood. (Kazmeyer Milton, Demand Media).

Fossil fuel consumption is more for recycled corrugated board materials than making new from pulp. Fibre re-use is environmental friendly but energy is spent in transportation and remanufacturing as well. Paper factories generate energy with steam turbines to the public grid and excess electricity can be used for the company's own production needs or sold to national electricity network.

The internet page of Rainforest: Asia Pulp and Paper Group is generating energy from what the paper industry has long considered waste. The company's newest innovation is technology to generate methane from wastewater, and to recycle the gas as a fuel to power production. (Rainforest).

Box on Pallet is an alternative solution for containers. NSN is making cost efficient pallet loads by using box on pallet deliveries as seen in figure 7. Box on pallet makes the best use of pallet loads and creates saving in transportation and storage costs by minimizing packing material usage. The concept is supporting the requirements in regulations well.

FIGURE 7. Box on pallet stacking

5.3 Plastic materials

The life cycle assessment included plastic straps, bags, wrapping plastic foil, air cushion and plastic tape. Also printing ink used for materials marking was evaluated. Based on the material data information from suppliers plastic based packing items don’t include any banned substances.

Unit packing straps are used as a lifting handles and container is secured to the pallet by straps. Recycled material available from PET bottles is used as a recycled raw material for straps. Other plastic items are mainly done from virgin materials.

The biggest environmental impact area of plastic products is depletion of abiotic resources caused by usage of fossil fuel oil. Also, the climate change due to production processes and transportation can be seen in the analysis as well as some acidification impacts

Air cushion and kraft paper are used for filling empty space in container. Filling material has to be used for cushioning and to prevent the movement of boxes in the container. Paper and plastic fill are never mixed for one container, which makes waste sorting and recycling easier. Kraft paper can be re-used for same purposes or as a raw material or as energy whereas air cushion is made of plastic and thus only reuse as energy is possible.

According to Ecolife, plastic bags takes 10-20 years and strap 450 years as an example of how long non biodegradable item takes to break down naturally when they are scattered around as litter (assuming an adequate supply of oxygen and moisture). Kraft paper as a biogradable item needs only 2-5 months to break down naturally. (Ecolife, 2011).

5.4 Plywood pallet

Based on the material data information from suppliers plywood pallets do not include any banned substances. Formaldehyde is strictly controlled and banned item in wood and wooden material, e.g. packaging with a limit of 0.1 ml/m3. Amount should not exceed limit which is measured as formaldehyde release into the air by a special testing procedure. All suppliers have measured the emissions into the air accordingly and confirmed limit is not exceeded.

The biggest environmental impact areas are climate change caused by plywood production, depletion of abiotic resources since renewable wood is used and some acidification impacts.

NSN plywood pallets are reused several times similar way as containers. Reuse has decreased need of new pallet remarkably. Incineration is a more preferred option than sending pallets to landfill.

Wood or plywood takes 1-3 years as an example of how long biodegradable items takes to break down naturally (assuming an adequate supply of oxygen and moisture). (Ecolife, 2011).

5.5 Metal pallet

Metal pallet do not include any banned substances based on the material data information from the drawing. The total environmental impact of the metal pallet is higher than the one of plywood pallets. Metal pallet has additional transportation from site back to hub (re-use). Environmental issues do not support re-usable aluminium pallet usage even it is estimated to be re-used eight times in this study, while the plywood pallet was considered to be single use only. Metal pallet is not recommended for incineration or landfill at all.

Metal pallet weight is much lower than plywood pallet. Aluminium and manufacturing it is causing high environmental impact. Compared with the production of primary aluminium, recycling of aluminium products needs as little as 5% of the energy and emits only 5% of the greenhouse gas.

Human toxicity is the biggest environmental impact caused by aluminium production. Abiotic depletion is the second biggest environmental impact due to mining of natural resource bauxite to produce aluminium. Global warming/climate change can be seen in the results due to electricity needed for production process and fuel needed for transportation.

Aluminium economy is a circular economy. For most aluminium products, aluminium is not actually consumed during a lifetime, but simply used. The life cycle of an aluminium product is not the traditional cradle-to-grave sequence, but rather a renewable cradle-to-cradle. Metal should not contain any traces of environmentally harmful paints or coatings.

Logistics during the transportation and customer site may not be ideal for reusable pallet. The damage rate is estimated to be as high as 40% and a lot of repair is needed. Each telecommunication vendor have their own metal pallet solution and thus NSN pallets are returned to other vendor, and NSN is receiving pallets belonging to other vendors. The return transportation of metal pallet for the right vendor is causing additional emissions. The proposal is to also look at logistics questions more deeply and consider if the metal pallet usage should be discontinued.

5.6 Desiccants

Electronic products can be sensitive for moisture. Purpose of desiccant is to remove humidity that can damage or even destroy product. Bentonite clay, silica gel and activated clay can be used as a desiccant due to their adsorption properties. Amount of dehydrant bags are determined in units according to DIN 55473 standard, which stipulates that the desiccant shall be chemically neutral and non deliquescent. One shipment contains more than one desiccant bag. Different desiccants variants were evaluated in this study.

Bentonite clay consists of natural minerals, which can be regenerated by drying them slowly. It is non-toxic and non-rusty and does not contain any additive nor calcium chloride. Bentonite has higher adsorption capacity than silica gel in the most common packaging environments. Disposal of bentonite is landfill only.

Silica-gel is made of silicon dioxide (SiO_2). It is essentially porous sand and non-hazardous. Silica-gel is capable of physically adsorbing 40% of its weight in water vapour at 100% humidity into its internal pores without chemical reaction.

Silica-Gel moisture-indicators are poisonous substances and at NSN only clear silica-gel is used.

Activated clay is a naturally occurring biodegradable material made from natural clay minerals. It is 100% degradative and has adsorption capacity up to 75% of its own weight. It is safe, odourless, non toxic and non corrosive. Adsorption rate is 50% - 100% higher than silica gel.

Based on the material data information from suppliers, desiccants used by NSN do not include any banned substances. Only non-poisonous desiccants are used by NSN. Desiccants do not pollute the environment since material from nature is used. Information of production process impacts was not available and materials only have small environmental impacts for global warming and depletion of abiotic resources in this life cycle assessment.

5.7 Tapes, stickers and plastic film

Life cycle assessment also included NSN plastic film, paper tape, and plastic tape as well as identification stickers (labels). Based on the material data information from suppliers' identification sticker, printing ink, plastic film, plastic tape, paper tape and glue used in these products do not include any banned substances.

Plastic film (polyethylene) is used for both inbound and outbound packing (figure 7). The purpose is to protect shipment from dirt and water splash as well as bind the pallet load. Plastic tape (polypropylene) is used mainly for closing unit packing. The biggest impact area for plastic tape and film is depletion of abiotic resources due to usage of fossil fuel oil. Also some climate change is caused due to production processes and transportation, which can be seen in the analysis. Some acidification impacts are caused by manufacturing processes.

Paper tape is used for both closing a container and as a moisture sealing. The same is applicable for heavy duty corrugated board boxes, which are used for deliveries without a container. The biggest impact area is depletion of abiotic resources due to usage of renewable wood as a raw material. The climate change due to production processes and transportation can be seen in the analysis. Some small acidification impact is caused as well.

Every unit box and container has an identification sticker. It includes printed data of the product inside the box or container (code, unit name, country of origin, bar code etc). The biggest environmental impact area for labels is depletion of abiotic resources due to the usage of renewable wood as a raw material. The climate change due to production processes and transportation can be seen in the analysis. Some small impact of eutrophication air and water emissions is also visible.

6 CONCLUSIONS

Life Cycle Assessment gives a good guideline where to go even if may not show the absolute truth. There is always a room for improvements and reason to look for more sustainable packing solutions.

Comparing assessment of the NSN BTS product life cycle results and assessment of the packing life cycle results was not feasible. However these two LCA's can be combined together for getting a bigger picture of all impacts. The BTS production energy consumption is so much bigger and material contexts totally different from the packing items. The impacts of the packing material environmental are very small compared to the BTS products.

The outcome of LCA is as good as the information entered to the system. Some suppliers gave very accurate data while some others gave more average data. It was also very challenging to get data from "cradle to the grave" LCA.

LCA allows suppliers to emphasis results which are good for they own products. As a producer of expanded polystyrene cushions LCA can be made to favor them objective view. One must keep objective view for all results since they are not black and white. Reuse may not always be the only driver for most environmental solution even it is rated high by EU.

NSN packing platform is based on R3 policy even term is not used.

Reduce, Reuse, Recycle (R3) is an environmental methodology and strategy for waste minimization. R3 is a hierarchical waste framework that is used to generate maximum product benefit with minimal waste. (Techopedia, 2010).

Packing designers are using minimum amount of packing material for maximum protection. Reuse and recycling are handled well. As generally known, there is also room for improvement in several countries. Each individual person has one's own environmental behaviour and it is impossible to control everyone. By providing training NSN can continue to increase the awareness of recycling and the importance of reuse.

LCA confirms original assumption that NSN is using environmental friendly packing solutions to be correct. No alarming questions were found in the assessment. Transportation has the major environmental impact. NSN avoids unnecessary material movements by having suppliers as close to the packing material use location as possible.

LCA confirms NSN packing design rules to be right:

- Minimize material usage.
- One packing solution not to include several different materials enables easy recycling.
- Design rule to minimize packing size can be seen impacting on the logistics via good volumetric efficiency.

The material recycling value is not visible in LCA SimaPro models since data was not available. A high recycling rate has been verified to be in use for NSN packing items both as sustainable activity as well as a good cost saving by other references in this document.

6.1 Environmental questions/problems in packing designer work

It is important for a packing designer to keep environmental “green” questions mind while making the actual design work. These questions were collected as a list while this LCA study was being done.

NSN has always followed the environmental regulations and changed packing designs and design principles accordingly. Most of the emphasised questions are already known and included in the current designs. Now the sustainable packing design list is documented and they are easy to follow. The list will be forwarded to the NSN packing design team.

- The first option is to use existing packing item instead of making a new design. Avoid designing several corrugated board box with only minor size difference, especially height varies. Consider the possibility to use existing cushions. Consider the design impacts to the mould design (new mould, change existing mould, is existing mould available in same country as needed etc).
- Always look for the end-to-end solution. Remember that reuse or any other point is not the only driver in decision making. One reuse question can cause challenges, problems, costs, harmful environmental impacts to warehousing, manufacturing, packing line, transportation optimization etc.
- Recyclable materials should be used. Select materials which have wider reuse potential.
- Prefer corrugated board material instead of plastic/EPE/EPP whenever possible. Corrugated board material is easy to reuse, recycle and has low environmental impact. Plastic is reused only for energy creation.
- It is preferred to use perforation instead of printing whenever possible, as printing colour, especially black, includes very small amount of lead without exceeding limit 0.01% by weight. Perforation is marking without printing colour and additives (marking with small holes). Supplier capability to perforation varies. To ensure production capability drawing can include optional perforation or printing.
- Colour is always an additional substance. Consider defining it for packing items only if necessary as an indicator (for example ESD), graphics manual specifies using it (brand logo) or for other specific need. Suppliers need to clean pipes before producing different colour for expanded cushions in production line. By reducing additional cleaning needs we can help supplier to reduce environmental impacts (reduce removing residues from cleaning water, energy and water saving etc).
- Make designs consuming minimum amount of material and reduce production waste material. Communication, CAD design tools and co-operation with suppliers will help the designer to understand productivity

- factors, minimize material usage and make cost efficient design in all means.
- Keep in mind the maximum product safety with minimal material. The purpose of the packaging is that the product arrives for the customer in perfect condition. It is very big waste of resources if it does not.
- “Out of a box” thinking not to make only standard packing designs even design work is hectic. Consider optional materials, innovative design solutions, harmonizing new packing design to be suitable for any existing product, one solution for volume production and reverse logistics, minimize tooling and investment needs etc.
- Reduce packing weight and optimize size for transportation volume by thinking total end to end concept instead of making only unit packing solution. In order to find ideal box size you need to make pallet and container simulation at early phase of design work. Keep in mind minimal material for maximum safety.
- Sustainable design is not always a one-size-fits-all concept. Packing design must be adapted based on the life cycle profile of the specific product, the business strategy and the culture and capabilities of the organization (moulded cushion may not be feasible for low volume products, customer packing specification may include other requirements than NSN specification, corrugated board pallet is sustainable but may have a lot of damages due to rough handling etc).
- Innovative use of packing items included in design. Can box be used also as a drilling template when needed, could cushion be visually limiting packing mistakes and supporting the Poka yoke principle (hole in cushion for each accessory items) etc.
- Generic packing guidelines and instructions must support sustainable packing solutions. Minimize and eliminate additional over packing by defining rules when desiccant, barrier bag, ESD property etc are needed.

6.2 Other findings and improvement areas

While doing this study, some potential packing material inbound improvement areas have also been identified.

The packing materials are packed for delivery from the manufacturing plant to the NSN location of use. The purpose of the packing is to secure the delivery from damages and dirt. Some packing items consist of two or more items, which packing is kitting together (like cushions). Several variations can be seen in (figure 8) how incoming packing materials are currently packed.

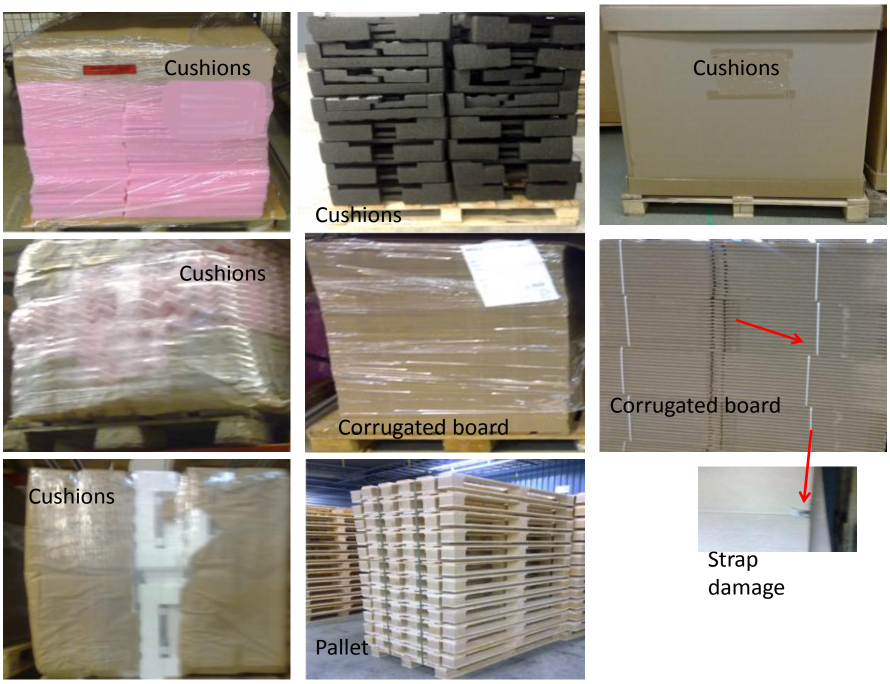

FIGURE 8. Solutions for incoming packing material

The following potential improvement areas are proposed for the incoming material packing:

- Maximum number of items inside a bag, container or on a pallet.
- Plastic film wrapping not to be used if it is duplicate protection.
- Additional paper covers can be removed if plastic is used.

- Remove unnecessary straps. Bundling cardboard material with a strap can damage the first and last boxes. It is an extra work step to remove strap and they are additional waste.
- Pallet size to be optimized for outbound re-uses purposes.
- Purchase lot size to be the same for multisource products.
- Pallet packing is a good example of effective packing.

Electricity generation and fuel needed for transportation are the largest sources of the greenhouse gas emissions that contribute to climate Change. Packing material vendors in this LCA are using either coal or gas for energy creation. SimaPro analysis shows that coal has bigger environmental impact than natural gas (figure 9). Gas is a very good fuel to create energy, it creates less carbon dioxide emission than other fossil fuels and also other environmental impacts are small compared to other fuels.

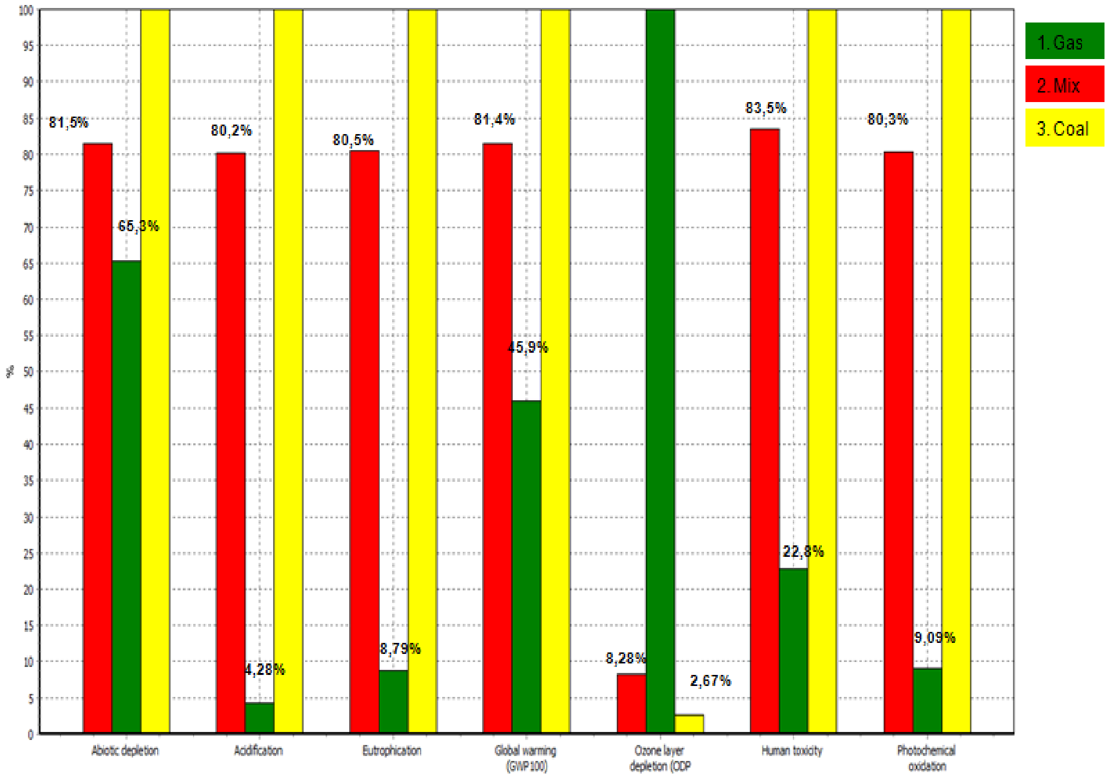

FIGURE 9. Comparing energy creation 1 MJ coal to gas and mix coal/gas

Paulina Jaramillo has compared coal and natural gas LCA for electricity generation in her PhD Thesis.

It is better to use clean coal technologies for electricity creation then import natural gas. Countries which have natural gas available should use electricity based on it in order to create less GHG emission than coal. Without knowing natural gas availability for different suppliers, it is not possible to select optimal solution. However energy usage can be considered as a one green value when making supplier selections. (Jaramillo Paulina, 2007).

6.3 Transportation

Transportation is with no doubt one big reason to create environmental impacts. NSN selects packing material manufacturers close to the location of use. The inbound delivery distance is fairly short and thus no major impacts can be seen in this study.

Finished products are delivered from NSN hub to the customer warehouse, which can be located anywhere in the world. The impact of 1000 km transportation by road and by air has been evaluated in this study. The environmental impact of air delivery is much higher than any other delivery mode. By using SimaPro models, it is visible that sea freight is preferred to be used for transportation whenever feasible, whereas delivery by air should be avoided.

Logistics is responsible for a variety of externalities, including air pollution, noise, accidents, vibration, land-take and visual intrusion. Emissions from freight transport largely depend on the type of fuel used. Various alternative fuels now exist. However, the main fuel used by goods vehicles continues to be diesel, with relatively small amounts of freight moved in petrol-engined vans. Trucks and vans emit pollution mainly because the combustion process in their engines is incomplete. Diesel and petrol contain both hydrogen and carbon. If it were possible to achieve perfect combustion, 100 per cent of the hydrogen would be converted into water and all the carbon into CO_2. However, because combustion is not complete, tailpipe emissions of pollutants such as hydrocarbons, carbon monoxide and nitrogen oxides result (Holmen and Niemeier, 2003). (McKinnon Alan, Browne Michael, Whiteing Anthony, 2012, 31-32).

7 DISCUSSION

The purpose of this Master’s thesis was to create an assessment of product packing material life cycle for NSN and to create an Excel-based tool. The data collection phase was very time consuming and work took more time than originally assumed since I had to wait for information from the suppliers. The theory is very much based on the LCA tool instructions as well as the standards.

The SimaPro tool was used for Life Cycle Analysis. In the beginning there was a challenge to learn to use this SW without having a proper training. It took quite a while but with a support from a colleague and good user manuals I managed to create the models.

The quantitative method is used in the LCA assessment. The product, process and environmental impacts were analyzed from the packing material suppliers to the point when the end user is unpacking and removing the packing for reuse.

After the theory was created, the writing of the Master’s thesis went smoothly since the results and findings had been collected and reviewed by the steering team earlier. The need for an Excel based tool was not created, as the need for it was not seen after further clarifications.

After the steering team had reviewed the LCA results, new needs rose up. Based on the findings, the evaluation of the metal pallet usage has been created in more detail. Additionally, specific presentation material was created for packing designers about the environmental questions they need to know and take into account.

As a conclusion, NSN is already using environmental friendly packing materials and correct decisions have been done earlier. As a continuation for the environmental study, a new project related to more sustainable packing solutions has been started. The knowledge gained through creation of this thesis work has already been very beneficial for my daily work in the NSN department of global product packing solution. I now have good knowledge to emphasis fact based green values in my daily work and new coming projects.

8 REFERENCES

An Overview of the RAINS Model, Environmental Research Centre Report, 2006. Available at:

http://www.epa.ie/downloads/pubs/research/air/epa_overview_of_rains_model_erc4.pdf. Visited 6.2.2013.

British standard, EN ISO 14040:2006, 1.7.2006, [pdf].

British standard, EN ISO 14044:2006, 31.8.2006, [pdf].

British standard, SFS- EN 13430:2004 Packaging - Requirements for packaging recoverable by material recycling, 3.3.2005, [pdf].

British standard, SFS- EN 13431:2004 Packaging - Requirements for packaging recoverable in the form of energy recovery, including specification of minimum inferior calorific value, 3.3.2005, [pdf].

British standard, SFS- EN 13432:2004 Packaging - Requirements for packaging recoverable through composting and biodegradation. – Test scheme and evaluation criteria for the final acceptance of packaging, 3.3.2005, [pdf].

Circular Economy Promotion Law of the People's Republic of China.Translation available at :

http://www.amcham-shanghai.org/NR/rdonlyres/4447E575-58FD-4D8E-BB0F-65B920770DF7/7987/CircularEconomyLawEnglish.pdf. Visited 28.1.2013.

Directive 2008/98/EC on waste (Waste Framework Directive). Available at:

http://ec.europa.eu/environment/waste/framework/index.htm. Visited 26.12.2012

Ecolife, 2011. Available at:

http://www.greengood.com/terms_to_know/biodegradable_definitions.htm. Visited 3.2.2013.

EIA track data base, English translations for China packing related environmental laws. Available at:

http://www.eiatrack.org/. Visited 1.2.2013.

Environmental benefits of re-cycling versus re-use, Fefco, 2003. Available at:

http://www.opakowania.net/porady/dok/Triptique-03.pdf. Visited 26.12.2012.

European Commission, 2004. Packaging and Packaging Waste Directive 94/62/EC amended with 2004/12/EC. Available at:

http://ec.europa.eu/environment/waste/framework/index.htm. Visited 5.6.2012.

European Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste. Available at:

http://ec.europa.eu/environment/waste/landfill_index.htm. Visited 8.1.2013.

European Commission, 2006. REACH, European Community Regulation on chemicals and their safe use (EC 1907/2006). Available at: http://ec.europa.eu/environment/chemicals/reach/reach_intro.htm. Visited 29.8.2012.

European Database for Corrugated Board Life Cycle Studies 2003. Available at:

http://www.fefco.org/sites/default/files/documents/2009_LCA_report_Fefco.pdf. Visited 10.6.2012.

Green Good 2012. Available at:

http://www.greengood.com/terms_to_know/biodegradable_definitions.htm. Visited 4.2.2013.

Introduction to LCA with SimaPro 7, Mark Goedkoop, An De Schryver, Michiel Oele, Sipke Durksz, Douwe de Roest. 2010. Available at:

http://www.pre-sustainability.com/download/manuals/SimaPro7IntroductionToLCA.pdf. Visited 15.3.2012.

Jaramillo Paulina. 2007. A Life Cycle Comparison of Coal and Natural Gas for Electricity Generation and the Production of Transportation Fuels. Available at:

http://wpweb2.tepper.cmu.edu/ceic/theses/Paulina_Jaramillo_PhD_Thesis.pdf. Visited 13.9.2012.

Järvi-Kääriäinen, Terhen, Ollila Margareetta, 2007. Toimiva Pakkaus. ISBN 978-951-8988-41-3.

Järvi-Kääriäinen, Terhen. 2011. Pakkaussuunnittelijan työkalulaatikko ympäristömyötäisyyden edistämiseksi Suomessa. ISBN 978-951-8988-45-5. Available at:

http://files.kotisivukone.com/ptr.kotisivukone.com/rap_58_pakkaussuunnittelijan_tykalulaatikko_25.1.20112.pdf. Visited 3.4.2012.

Kazmeyer Milton, Demand Media. How much energy does recycling save? Available at:

http://greenliving.nationalgeographic.com/much-energy-recycling-save-2363.html. Visited 5.3.3013.

Landfill Directive 99/31/EC. Available at:

http://ec.europa.eu/environment/waste/landfill_index.htm. Visited 5.3.2013.

McKinnon Alan, Browne Michael, Whiteing Anthony. 2012. Improving the environmental sustainability of Logistics, Kogan Page Limited, p 31- 32, 35. ISBN-13: 9780749466251.

Nokia Siemens Networks, sustainability statement. Available at: http://www.nokiasiemensnetworks.com/about-us/sustainability. Visited 8.9.2012.

PE-International, GaBI, Software for Life Cycle Assessment. Available at: http://www.pe-international.com/nw-eu-english/software/. Visited 29.6.2012.

PRé Consultants, SimaPro LCA Software. Available at:

http://www.pre-sustainability.com/simapro-lca-software. Visited 29.7.2012.

Rainforest, Renewable energy helps pulp and paper mills reduce carbon footprint, increase energy independence. Available at:

http://www.rainforestrealities.com/articles/renewable-energy-helps-pulp-and-paper-mills-reduce-carbon-footprint-increase-energy-independence/. Visited 5.3.2013.

REACH, European Community Regulation on chemicals and their safe use (EC 1907/2006). Available at:

http://ec.europa.eu/environment/chemicals/reach/reach_intro.htm. Visited 5.3.2013.

Reusable packing association. Available at:

http://reusables.org/why-choose-reusables/what-is-reusable-packaging. Visited 26.12.2012.

RoHS Directive 2002/95/EC. Available at:

http://ec.europa.eu/environment/waste/rohs_eee/. Visited 5.3.2013.

SimaPro 7, database manual, 2008. Available at:

http://www.pre-sustainability.com/download/manuals/DatabaseManualMethods.pdf. Visited 24.9.2012.

SimaPro 7, Introduction into LCA, 2010. Available at:

http://www.pre-sustainability.com/download/manuals/SimaPro7IntroductionToLCA.pdf. Visited 3.1.2013.

SimaPro 7, LCA Methodology. Available at:

http://www.pre-sustainability.com/lca-methodology. Visited 3.1.2013.

Styrene forum. Available at:

http://www.styreneforum.org/index.html. Visited 1.2.2013

Techopedia, 2010. Available at:

http://www.techopedia.com/definition/14225/reduce-reuse-recycle-r3. Visited 23.12.2012.

Umberto, Software for Life Cycle Assessment. Available at:

http://www.umberto.de/en/. Visited 28.6.2012.

World aluminium, Global Aluminium Recycling, 2009. Available at:

http://www.world-aluminium.org/media/filer/2012/06/12/fl0000181.pdf. Visited 28.12.2012.

United Nations Environment Programme, 2007. Life Cycle Management, a business guide to sustainability. Available at:

http://www.unep.org/pdf/dtie/DTI0889PA.pdf. Visited 2.1.2013.

Ympäristöministeriö, 17.8.2012. Available at:

http://www.ymparisto.fi/default.asp?node=3371&lan=fi#a2. Visited 5.2.2013.