LUND UNIVERSITY

Lund University Master's Programme in Environmental Science

Is ecological living in Sweden different from conventional living?

-A case study of the ecological village Toarp and the conventional town Oxie in south Sweden

Master's thesis
December 1998

By

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Acknowledgement

The author wants to give thanks to the following people for assistance and inspiration: the supervisors *Janusz Niemczynowicz, PhD (Department of Water and Resources Engineering, Lund University) and Mats Svensson, PhD (Department of Chemical Engineering, Lund University).* Pernilla Ahlgren, Mathis Wackernagel, Harald Sverdrup, Ingegerd Ehn, Åsa Grunning, Siv Adamsson and all the other teachers and students at Lumes and Lund University. A special gratitude is given to Elsa Hermansdóttir, my mother, for all the help through all these years.

Man is like every other species in being able to reproduce beyond the carrying capacity of any finite habitat. Man is like no other species in that he is capable of thinking about this fact and discovering its consequences.

William R. Catton, Jr.

Abstract

Ecological Footprint analysis (EF) was used to determine whether so called ecological living in Sweden differs from conventional living. Two cases where considered, the ecological village Toarp, and the reference town Oxie, which are both situated in south Sweden. The study involved three elements: 1) Calculations of material and energy needs for constructing an eco-house in Toarp and a standard house in southern Sweden, 2) ecological footprint analysis of consumption patterns in households from Toarp and Oxie, 3) dynamic simulation of the Swedish national footprint.

Only 10% difference is observed from the footprint comparison of the building materials between an eco-house in Toarp and a standard house. Building materials represent less than 5% of the annual ecological footprint in Toarp and Oxie.

Currently there is "no" statistical difference in the footprint between Toarp and Oxie. The average annual footprint in Toarp is 2,8 ha/capita and 3,7 in Oxie respectively. Greater number of people residing per households in Toarp explains this difference. Food consumption and energy consumption for housing (space heating and electricity use) are the largest contributor to the footprint in Toarp and Oxie. These factors are almost equal in size and constitute 75% of the total footprint in both Toarp and Oxie.

Of the total 5,9 hectare footprint per capita per year in Sweden, households contribute on average 3,2 hectare and the governmental/industry sector 2,8 hectare. If households decrease its footprint by 70% and the governmental/industry sector reduces its footprint by 90% over the next 40 years, Sweden can achieve ecological footprint that is below the *fair Earthshare* and become ecologically sustainable.

Key words:
Ecological footprint, eco-living, conventional living, Toarp, Oxie, Sweden

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1.0 Introduction

Current development of global economies presents an increasing problem for balancing consumption level with available natural resources. It is becoming clearer that the greatest challenge for the 21st century is to secure the quality of life within the means of nature. Today, the concept sustainable development is used in many ways in our daily lives to describe certain status of products or projects. Lack on information and knowledge on the concept sustainable development, has often led to confusion on how to formulate goals and strategies to reach sustainability. People talk of sustainable farming, tourism, etc without comprehending a deep knowledge of the meaning. Projects are often only assessed in terms of local impacts and exclude the indirect consequences of the actions. In a global economy, consumption is no longer necessarily felt locally but indirectly throughout the world in various form of production, transport, and services. To be able to estimate activities as sustainable, an environmental accounting is needed to assess the ecological load. The Ecological Footprint analysis takes the term sustainable development into a measurable context and enables us to assess hidden factors often not seen in conventional assessment. The current estimation on global consumption reveals that humans are in 35% overshoot on existing natural capital. The most important issue for politicians and the common people is to choose wisely the path towards sustainable future. Ecological villages are seen as one of many stepping stones towards reducing the impact on the environment. In depth knowledge and understanding of ecological villages is required on an interdisciplinary level if actions and important implementations are to succeed. This study will shed some new light on the current development of ecological living and put the concept into broader perspective, which hopefully increases understanding of ecological villages and their connections to society.

1.1 Background

Much is debated in Sweden on what measures are needed to reach sustainable society. Large shares of that debate have been allocated on ecological living and the importance of building ecological houses and living ecologically. Policy makers are often faced with different opinions and options on how to reduce the ecological load of the society. Although many researches have been conducted on ecological lifestyle, not many have been focused on quantifying its load in a global perspective.

1.2 Objectives

This research sought to quantify the environmental load of the eco-village Toarp and its reference town Oxie, using the ecological footprint methodology. The over all aim of the study was to answer the question; is ecological living in Sweden different from conventional living in terms of energy used for construction of buildings and energy used for living? The second objective was to study the trends in the developments of the Swedish footprint and analyse how much the Swedish consumption has to be reduced to reach a footprint level below the limit of a *"fair Earthshare"*.

1.3 Scope and limitations

This study covers the ecological village Toarp and the conventional town Oxie, which are both situated in south Sweden. Three studies where covered in the research: Calculations of material and energy needs for constructing an eco-house in Toarp and a standard south-Swedish house, ecological footprint analysis on the consumption lifestyle in Toarp and Oxie, and simulation of the Swedish national footprint.

1.4 Methodology

Three methodological approaches were used: The Lifecycle inventory analysis, the ecological footprint analysis and simulation modelling using systemic approach (see Appendix I, chapter 9).

1.5 Disposition

The thesis consists of two parts. The first part is the research, which constitutes the main body of the thesis (chapter 1-6). The second part (Appendix I) is a background to environmental problems. It includes comprehensive literature review containing description of relevant theories and methodologies used in the study.

2.0 Introduction to the case study in Toarp and Oxie

This chapter will describe the cases used in the study, the Toarp eco-village and Oxie. Toarp is a good choice for a comparison study. It was designed and constructed using the principles and definitions given the Swedish Housing Ministry today. The reference town Oxie is situated next to Toarp and can be considered a typical satellite town outside Malmö, with conventionally constructed houses.

2.1 Toarp

Today there are approximately 150 buildings in Sweden, which are labelled as ecological (Thurell, 1996). Toarp is one of the so-called second generation of eco-villages, which is basically defined as low energy use, partially self reliance in food, and recycling of water/waste and materials (see chapter 8). Toarp is one of the more advanced eco-villages currently operating in Sweden (Lindén, 1997). It was in 1989 that politicians in Malmö started to show interest in building the community's first eco-village. Inspired of other eco-villages in Swedish such as Solby in Lund, the politicians took the initiative and laid down plans for a new eco-village. Unlike other eco-village projects where the ideas and motivation come from local inhabitants, the Malmö community had detailed plans on how to construct the eco-village and where to position it (Ericson, Johansson, 1994). After two years of preparations and discussions the construction started. The Toarp eco-village was ready build in 1992 and the first inhabitants moved in early 1993.

2.2 Oxie

Oxie is considered in this study as a normal south Swedish town. It is chosen as a reference town since it lies next to Toarp. Oxie is connected to the national power grid and to the municipal water system. Most of the houses in Oxie are heated by electricity but some houses use oil boiler for space heating. Since Toarp has a total area of 4.2 ha it was necessary to find a similar site in Oxie that was comparable to the eco-village. Houses in the reference village had to be of similar size as in Toarp, have similar garden area, similar family structure and approximately the same transport distance to Malmö. An area called Kyrkby in Oxie was thought to be very suitable for the purpose and two streets lying close to each other Pilevalsvägen and Bäckarängsvägen were chosen for the analysis. These two streets can be considered as typical Swedish households with typical Swedish consumption pattern. The density, or available space for inhabitants in the study area is similar to Toarp.

2.1.1. Technical information on Toarp

The design of Toarp was followed by the definition given by Wiberg and Persson (*In* Boverket, 1991) in 1990 (see table 10). The total area is 4,2 hectare, the village consist of 37 houses, which are positioned on south directed slope. The houses are constructed from natural materials, with extra pane of glass in windows and thicker walls for super insulation. For space heating, all houses are installed with heat exchanger, solar-collectors mounted on the roof and are installed with wood stove. The houses are partially ventilated by natural means. Water is collected from a local well. Grey water is treaded by a local root-zone facility (Frieberg, 1991, Hammer, 1992, Wiberg, 1998).

At the start of the operation, all houses where installed with dry sanitation (composting) toilets. But since the composting toilets where installed without sufficient knowledge and direction for use, the inhabitants faced major technical and operation problems. About half of the composting toilets were exchanged for water toilets. The water toilets are connected to the root-zone system and a local farmer collects the sludge. The composted excretory product from the dry sanitation toilets is utilised by the inhabitants themselves (Fittschen, I. Niemczynowicz, J. 1997).

2.1.2. Inhabitants and lifestyle in Toarp and Oxie

According to Lindén (1997), the lifestyle in Toarp is very similar to the western urban lifestyle in terms of transport, buying necessities and goods etc. To some degree, what can be said is contrasting in Toarp compared to the normal Swedish lifestyle is the tendency towards more family centred and co-operation between other groups and more time consuming lifestyle. Also further towards living that requires more manual handling and personal capacity (Lindén, 1997). Inhabitants in Oxie are considered as typical Swedish households, with conventional Swedish lifestyle and behaviour.

3.0 Methodology of calculations used in the study

This chapter explains the procedure of the different analyses made in the thesis. Three phases of studies were conducted to compare the ecological village Toarp and its reference village in Oxie;

A. Calculation of material and energy needs. *Lifecycle inventory* was conducted on the construction phase of an *eco-house* from Toarp and a *standard* south Swedish house.
B. *Ecological Footprint analysis* of different lifestyles, one of the eco-village, Toarp, and its reference village in Oxie.
C. *Simulations on consumption trends.* A simulation on the ecological footprint was carried out using the footprint results obtained from the households in Toarp and Oxie.

All results were converted to ecological footprint value.

3.1 Lifecycle inventory of Toarp and Oxie

This assessment was conducted by using *lifecycle inventory* (see chapter 9.2 for explanation) on the 10 main building materials of the standard south Swedish house and a house from the ecological village Toarp. Since the type of construction can vary from different urban areas, a *standard* south Swedish house was used as a reference house in the calculations of the construction phase and the assumption was made that the *standard* house could be a typical house for Oxie. The information and the data on the standard house was obtained from the building entrepreneur Skanska AB (Andersson, 1998). Information on the house form Toarp was obtained from PEAB AB (Larsen, 1998). The basic phases for building a house were identified and system boundaries were drawn around three basic factors (see figure 1);

1. *extraction of resources*
2. *manufacturing of materials*
3. *transport of materials*

Generally, construction of all dwellings happens to fall within these main categories. The main focus was put on energy and CO_2 emissions and data source from Berge (1992, 1995) and Bokalder & Block (1997) was used for the calculations. Recycling of raw material such as steel and aluminium is common in the industrial countries and those effects are accounted for in the calculations. Although in recent years recycling of building materials is increasingly becoming more important (Heino & Bruno, 1996) it is only recently it has become of some relevance but this research will focus on dwellings that are constructed from new materials.

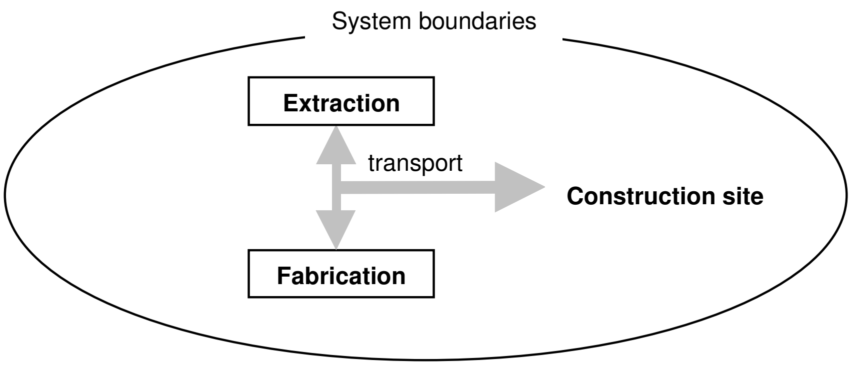

Figure 1: System boundaries are drawn around the extraction, fabrication and the transport phases.

3.1.1. Calculating energy to land

In evaluating the energy for different processes, the report from Björn Berge (1995) gave the most comprehensive information on primary production of building materials for the Nordic countries. In the research numbers representing the *extraction* process and the *fabrication* processes were mainly taken from Berge´s report. These numbers represent primary energy use (PEU) which covers the total energy needed for extraction of the resources and the fabrication of the building materials. The *Transportation* phase represents the energy needed to move the material from the *extraction* phase to the *construction* site. Information on this came from Bokalder & Block (1997) and Berge (1992, 1995).

Electricity in Sweden is mainly produced by nuclear- and hydropower and is therefore almost CO_2 emission free. Since nuclear energy has high operational costs and risk of failure, it is placed on an even basis with coal fired energy (see chapter 9.3.3) (Wackernagel & Rees, 1996). Thus the land required to sequester CO_2 from one nuclear energy unit equals one coal energy unit. In the primary production of different materials such as metals e.g. aluminium and steel, the manufacture procedure itself releases considerable amounts of CO_2. Many products are sources of CO_2 emissions despite of clean primary energy. Therefore CO_2 emissions here calculated are from materials in the production stage and in the transportation stage. According to Berge´s (1995), each material has a *global warming potential*, which is calculated as mean number of emission in building materials. This research uses these figures as a standard for calculations of emissions.

Matrix was constructed to compare the material quantities needed for the two villages. The energy need and CO_2 emissions were calculated and converted to total "ecological Footprint" value (see chapter 9.3 for explanations). The footprint value calculated was divided by the presumed lifetime of the houses, which is on average considered to be 50 years without heavy maintenance (Heino & Bruno, 1996).

3.2 Ecological Footprint analysis on Toarp and Oxie

The purpose of the Ecological footprint analysis (EF) was to compare ecological living to normal living. Toarp, which is situated in the outskirts of Malmö, was an excellent choice since it is considered one of the most advanced eco-villages in Sweden. One reference town had to be chosen that had same distance to the Malmö urban area as Toarp. Oxie was chosen as a reference town, since it positioned next to Toarp.

When comparing consumption levels of the two villages, Toarp and Oxie, a standardised method, developed by Wackernagel & Rees (1996) was used. The method, which is called *Footprint calculations matrix of households*, enables one to measure the annual ecological footprint generated by individuals by looking at the flow of average monthly consumption of their household. The consumption is divided into six categories, which represent different aspects of the consumption (see Appendix IV). After collecting data on consumption from a normal household, the data was then fed into a program called *"Footprint calculation matrix for households"*. This program estimates the annual footprint values on every member of the household.

The standardised questionnaire, which was used for evaluation, was translated directly to Swedish. Along with the questionnaire were attached questions about educational level and profession status (see Appendix IV). This was performed to see if there was a large difference in social background between the two villages and if it had an effect on the footprint value.

A total of thirty-five randomly selected households were asked to fill in the questionnaire about their monthly consumption. Eighteen forms were handed out in Oxie, and seventeen in Toarp.

3.3 Simulation of consumption trends

The Ecological footprint mirrors consumption in society, if consumption pattern changes, the footprint will also change. By estimating consumption trends in the future, it is possible to estimate the size of the footprint and see where the potentials for footprint decrease lies. A simulation on the ecological footprint was carried out by using the results obtained from the households in Toarp and Oxie (see chapter 4.2). Since the household EF is smaller than the total EF of Sweden, it is possible to identify the governmental/industry portion of the total EF. This was done by subtracting the Swedish national footprint value from the household footprint. The six main consumption categories in the *"Footprint calculation matrix for households"*: *food, housing, transport, goods, services and waste*, where simulated by using the software Stella 5.0. The simulation used data set from 1993, which ranks Sweden with EF 5,9 ha per capita (Ranking of Nations data from 1993, Wackernagel, 1998b, updated) to simulate the fair Earthshare (see chapter 9.3.1 for explanations). This data set has been updated in 1997 for new equivalent factors, in forest productivity and CO_2 absorption. A more recent study that is currently conducted on the Swedish national footprint shows slightly higher national EF values than the data set from 1993. These differences do not undermine the simulation processes, since the purpose of the simulation is to show trends and not actual values.

3.3.1 Modelling hypothesis

The model presenting the footprint simulation was based on the hypothesis that two main actors are behind the increase in the Swedish footprint, the household sector and the governmental/industry sector. The largest footprint contributors in the household sector are housing (electricity and space heating) and food consumption. If the Swedish households decrease their over all footprint by 70% for the next 15 years and the national governmental/industry sector reduces its footprint by 90% over the next 40 years, Sweden can reduce its national footprint level below the projected *fair Earthshare* in 2050 and possibly become ecological sustainable.

3.3.2 Model description

The model consists of two modules (see Appendix II), the first represents the *fair Earthshare*, and the second represents the Swedish national footprint. The national footprint is divided into six sub categories, which represent different aspects of the footprint. These categories are: food, housing, transport, goods, other household consumption and governmental/industry.

The results from the household footprint calculations were used to calculate the governmental/industry footprint by subtracting the difference from the national footprint value. The ratio of each household category within the household sector was identified and calculated as a ratio from the national value. The national footprint was initialised at value 1 hectare per person and then simulated by using above ratio. The *fair Earthshare* was simulated as an independent variable with a start value of 5.6 ha.

Five different scenarios were run with the model, which are supposed to correspond to possible implementation strategy towards sustainability. Potentials for decrease in the household sector were calculated and used in the simulation (see table 7 in chapter 4). These scenarios demonstrate how much is achieved with different actions and what is necessary to reach sustainability.

3.3.3 The model assumptions

When designing and running the model several assumption were made and are listed as following:

- **Footprint projection-** According to Wackernagel & Rees (1996) the footprint of the rich countries in the beginning of the century was ~1 ha per person. The assumption is made that Sweden had 1 ha footprint per person at the year 1900 and that it has increased 1.8% a year to the current national level of 5.9 ha per person (as calculated in 1993 data). It is also assumed that the behaviour of the footprint will not be exponential but sigmoidal. Meadow *et al.* (1992) foresees steep increase in resource scarcity within the next 50 years and as a consequence nations will have to either increase efficiency or consume less. Therefore it is assumed that Sweden's footprint will not exceed the 11 ha, which is the current footprint value of the US economy.

- **Eco- capacity**- According to FAO data (1998) world population is expected to reach 9,4 billion by 2050 and stabilise around 10 billions in following decades thereafter. According to Wackernagel (1998c) the available amount of all ecological productive land on Earth per person is today 2.2 ha. This is known as *fair Earthshare* (see chapter 9.3) The *fair Earthshare* has been steadily decreasing from 5.6 ha in the year 1900 to 2.2 ha in 1998 and is expected to slide down to 1.2 ha per capita by 2050. This study assumes that the world population will stabilise around 10 billion and with *fair Earthshare* of 0,9 ha in 2080.

- It is assumed that the population growth is responsible for 2/3 of the decrease in *fair Earthshare* and environmental degradation responsible for 1/3 of the decrease.

Following strategies are implemented in the model:

1. Reducing footprint of food consumption by 50% in households by consuming 50% less meat. Scenario implemented over 10 years.
2. Reducing footprint of lighting and space heating in households by 90%. Can possibly be done through factor 10 (efficiency, super insulation and renewable energy). Scenario implemented over 15 years.
3. Reducing footprint of transport, goods, services and waste by 50%. This would mean less dependency on fossil fuels, drive less, more train and bus commuting, as well as waste reduction. Scenario implemented over 15 years.
4. The governmental and the industry sector will reduce its footprint by 50%. Scenario implemented over 40 years.
5. The governmental and the industry sector will reduce its footprint by 90%. Scenario implemented over 40 years.
6. Same as number five, but here it is assumed that the international communities take actions in reversing environmental degradation.

All results from the simulations are presented in chapter 4.3

4.0 Results

Here are presented results from lifecycle inventory of the construction phase, footprint calculations of households in Toarp and Oxie, and simulations of the household data in comparison with the Swedish national footprint.

4.1 Lifecycle inventory of the Eco-house & the standard house

A lifecycle inventory was conducted on two different houses. One representative house from the ecological village Toarp and one house representing the reference town Oxie. The standard house used for Oxie is considered standard south-Swedish family house (Andersson, 1998).

This study extracted two kinds of data (see table 1). The first set of data describes the use of energy needed to produce the ten most common materials, and the energy needed for transportation of the materials. The second set of data describes CO_2 emissions, which are released from production and transportation of the same materials. As it is stated in chapter 9.3.3, all energy values can be converted to a hectare forest, corresponding the area that can produce the energy. When all the energy and the emission data were collected and assessed, it was converted to corresponding hectare land needed to support the energy. According to Wackernagel & Rees (1996), the consumption of 80-100 Gj fossil fuel per year corresponds to the use of one-hectare biological productive land. The value *~80 Gj/ha/year* was used in this assessment.

Table 1: Calculation matrix of the 10 most common building materials in the standard house and the eco-house.

Standart house	**units in kg per 100m²**	**P.E.U.**	**energy MJ**	**total kWh**	**kWh/m²**	**transp. Dist. km**	**kWh/ tonn transp.**	**total kWh**	**kWh/m²**	**CO_2 g/kg**	**ton CO2 PM**	**ton CO2 transp.**	**EF electr. Prod.**	**EF prod. phase**	**EF transp. Phase**
steel	256	6	1536	427	**4,3**	1000	0,13	460	**4,6**	250	0,064	0,008	0,010	0,04	0,004
aluminium	5	58	266	74	**0,7**	5000	0,17	78	**0,8**	1900	0,009	0,001	0,003	0,00	0,000
brick	12385	2	24771	6881	**68,8**	500	0,5	9977	**99,8**	160	1,982	0,713	0,155	1,10	0,396
concrete	37156	0,6	22294	6193	**61,9**	500	0,5	15482	**154,8**	120	4,459	2,140	0,139	2,48	1,189
gipsum	3761	5	18807	5224	**52,2**	300	0,5	5788	**57,9**	330	1,241	0,130	0,118	0,69	0,072
glass	138	7	963	268	**2,7**	600	0,5	309	**3,1**	600	0,083	0,010	0,006	0,05	0,005
mineral wool	527	11	5793	1609	**16,1**	500	0,5	1741	**17,4**	770	0,405	0,030	0,036	0,23	0,017
lose m/wool	1151	11	12660	3517	**35,2**	500	0,5	3804	**38,0**	880	1,013	0,066	0,079	0,56	0,037
paper	190	3,6	685	190	**1,9**	200	0,3	202	**2,0**	0	0,000	0,003	0,004	0,00	0,001
wood	938	3	2813	781	**7,8**	200	0,3	838	**8,4**	50	0,047	0,013	0,018	0,03	0,007
plastics	505	75	37844	10512	**105,1**	3000	0,17	10770	**107,7**	2000	1,009	0,059	0,237	0,56	0,033
expanded clay block	1564	2	3128	869	**8,7**	800	0,5	1495	**14,9**	230	0,360	0,144	0,020	0,20	0,080
total			131560	36544	**365**			50943	**509**		**11**	**3**	**0,82**	**5,93**	**1,84**

Toarp house	**units in kg per 100m²**	**P.E.U.**	**energy MJ**	**total kWh**	**kWh/m²**	**transp. Dist. km**	**kWh/ tonn transp.**	**total kWh**	**kWh/m²**	**CO_2 g/kg**	**ton CO2 PM**	**ton CO2 transp.**	**EF electr. Prod.**	**EF prod. phase**	**EF transp. Phase**
steel	260	6	1557	433	**4,3**	1000	0,13	466	**4,7**	250	0,065	0,008	0,010	0,04	0,004
aluminium	0	58	0	0	**0,0**	5000	0,17	0	**0,0**	1900	0,00	0,000	0,000	0	0
brick	13841	2	27682	7689	**76,9**	500	0,5	11150	**111,5**	160	2,21	0,797	0,173	1,230	0,443
concrete	31142	0,6	18685	5190	**51,9**	500	0,5	12976	**129,8**	120	3,74	1,794	0,117	2,076	0,997
gipsum	2595	5	12976	3604	**36,0**	300	0,5	3994	**39,9**	330	0,86	0,090	0,081	0,476	0,050
glass	433	7	3028	841	**8,4**	600	0,5	971	**9,7**	600	0,26	0,030	0,019	0,144	0,017
mineral wool	234	11	2569	714	**7,1**	500	0,5	772	**7,7**	770	0,18	0,013	0,016	0,100	0,007
lose m/wool	848	11	9325	2590	**25,9**	500	0,5	2802	**28,0**	880	0,75	0,049	0,058	0,414	0,027
paper	260	3,6	934	260	**2,6**	200	0,3	275	**2,8**	0	0,00	0,004	0,006	0,000	0,002
wood	865	3	2595	721	**7,2**	200	0,3	773	**7,7**	50	0,04	0,012	0,016	0,024	0,007
plastics	14	75	1038	288	**2,9**	3000	0,17	295	**3,0**	2000	0,03	0,002	0,006	0,015	0,001
expanded clay block	6055	2	12111	3364	**33,6**	800	0,5	5786	**57,9**	230	1,39	0,558	0,076	0,774	0,310
total			92500	25694	**257**			40260	**403**		**10**	**3**	**0,58**	**5,29**	**1,86**

The following sources and methods were used to analyse the difference between the two buildings:

> ***PEU-*** *Primary energy use (primer energy forbrug) data from Bjorn Berge, 1995: Bygningsmaterialer for en baerkraftig utvikling, NKB. Numbers are in MJ/per kg produced. The numbers are values from production within the Nordic countries. (In this research it is assumed that production and transport is relative low cost factor within the Nordic countries and well competitive with material from central Europe)*

KWh/ ton transport- *According to Björn Berge, 1992 the energy consumption ratio per unit transport is following: kWh/ton/km, large trucks 0,5, trucks w/(henger) 0,30-0.35, electric trains 0,11-0,13, Freighters 0,17, Flight 9,8*
Transport *distances and transport methods of the building materials are estimates by the author.*
CO_2 g/kg- *From Björn Berge (1995),* ***ton CO_2 transport-*** *calculated from Björn Berge (1992) and Fredrik Bertilsson (1995), Carbon Dioxide abatement… [p32].*
EF electricity production- *This is footprint from electricity production in Sweden which is 50% nuclear and 50% hydro. Nuclear energy if incorporating high operation costs and* ***risk of failure*** *is on even basis with fossil fuel. In that term nuclear energy equals fossil fuel energy ratio (80Gj/ha/year).*
EF production phase- *This comes from CO_2 emissions from producing the materials. E.G. producing aluminium will result in CO_2 emissions from the smelting process. One-hectare land of average forest can approximately sequester 1.8 tonnes of CO_2.*
EF transport phase- *the CO_2 emissions data from different transport sources is converted to hectare productive land needed to sequester the gas. The ratio 1.8 tonnes/ha is used. Data comes from Fredrik Bertilsson, (1995).*
Data on the south Swedish standard house *was given by Bertill Anderson at Skanska AB Malmö. He considers the building method and the materials very typical for south Sweden. Calculations are based on 218m^2 house.*
Data on the Eco- house *in Toarp comes from the building entrepreneur PEAB AB Malmö, contact person Rune Larsen. This particular house is 115,6m^2.*

The following table 2 summarises total energy and emissions from the production phase and the transport phase and converts these into corresponding footprints areas.

Table 2: summary on each house per 100 m^2

Comparison p/ 100m2	GJ P.E.U.	GJ P.E.U. & transp.	tons CO_2 prod.	tons CO_2 transp.	CO_2 total	footprint in hectare
standard	131,6	183,4	10,7	3,3	14,0	8,6
Toarp	92,5	144,9	9,5	3,3	12,8	7,7
difference %	**29,7**	**21,0**	**10,8**	**-1,2**	**7,9**	**10,0**

These results do only reflect the material use and their transport to the building site. It does not take into consideration the activities of the building entrepreneurs during the building process. Berge (1992) estimates that these activities can raise the total energy use by 10%.

According to Heino & Bruno (1996) the approximate lifetime of a family house before being subjected to large maintenance is 50 years. By dividing the footprint value from the construction phase with 50 years, the annual footprint from the building material is obtained. This annual footprint value for the construction phase is added to the total footprint number obtained from the households in Toarp and Oxie. Since there is only 10% difference between the two building methods, used in construction of the two residential areas considered, the averages EF number from both examples can be used as a common footprint value for building materials in Toarp and Oxie. In that case the impact from the building process is on average 0,16 ha/year during 50 years.

4.2 Results from footprint calculation of Oxie and Toarp

Out of total 35 forms that were given to families in Toarp and Oxie, a total of twenty forms were received from both places, ten answers came in from Oxie and ten from Toarp. After sorting out and evaluating the forms, all the answers were run through the *Footprint calculation matrix for households,* for calculations. The number of people in the households that returned the forms are following; in Toarp: 20 adults, 19 children, in Oxie: 20 adults, 10 children.

In some cases, people did not fill out completely the household form and left thus some entries with question mark or other remarks to indicate that the knowledge of that particular item was not at hand. To compensate for that, an average value from that particular village was calculated and inserted. A comparison between academic and professional background was made between the towns. Following table 3, lists summary of the results from each category in square meters and total hectare each household uses for its consumption. An average hectare value for each village was obtained. Since the samples where randomly taken from each town, the alphabetic order does not mean comparison between individual houses.

Table 3: The footprint value from each household category is displayed in m^2 biological productive land and also in average ha.

Toarp (m^2)	A	B	C	D	E	F	G	H	I	J	average ha
Food	8 423	7 410	7 834	5 397	5 269	13 244	10 972	17 129	11 002	6 553	**0,93**
Housing	10 627	11 488	11 585	7 859	13 569	10 813	11 188	15 592	10 570	11 221	**1,15**
Transport	1 213	5 063	1 555	2 234	5 832	6 108	5 970	6 477	4 596	3 218	**0,42**
Goods	542	1 533	1 604	551	179	420	1 226	1 769	6 014	1 537	**0,15**
Services	247	256	283	246	1 882	532	520	529	3 907	383	**0,09**
Waste	504	342	478	145	193	305	360	210	784	725	**0,04**
total hectars	2,2	2,6	2,3	1,6	2,7	3,1	3,0	4,2	3,7	2,4	**2,8**

Oxie (m^2)	A	B	C	D	E	F	G	D	I	J	average ha
Food	18 537	15 223	20 850	6 789	12 688	10 862	16 182	7 350	10 869	16 910	**1,36**
Housing	13 777	16 938	26 726	7 564	10 677	22 483	12 167	4 078	6 875	19 721	**1,41**
Transport	8 823	7 573	232	5 139	1 896	9 287	8 314	1 738	3 435	2 938	**0,49**
Goods	2 197	6 399	1 008	1 242	1 051	4 263	6 158	1 754	962	3 160	**0,28**
Services	381	561	427	824	835	459	1 977	279	483	595	**0,07**
Waste	537	2 478	186	441	948	568	1 322	498	208	883	**0,08**
total hectars	4,4	4,9	4,9	2,2	2,8	4,8	4,6	1,6	2,3	4,4	**3,7**

If we include the embodied footprint from the building process, (see table 2) the numbers will increase slightly:

Toarp: **~3,0**
Oxie: **~3,9**

The construction phase contributes less than 5% of the total footprint flow in Toarp and Oxie, given that the footprint level in the households will hold through the lifetime of the house.

4.2.1 Statistical evaluation of Toarp and Oxie

A series of statistical tests were run on the samples to see if any significant difference was detectable between the samples. Following tests where run in the *NCSS97* statistical program*: descriptive statisitics,* the *Omnibus test* for normality, the *Modified Levene Equal-variance test*, and the non-parametric test Mann-Whitney for difference between medians in two samples. Non-parametric test was chosen since the sample sizes were small, and furthermore they are more powerful when there is an uncertainty of normality in the samples. From the descriptive calculations following results were obtained (table 4):

Table 4: Results from descriptive statistics.

observation	toarp	oxie
n=	10	10
mean	2,78	3,70
median	2,65	4,4
standard deviation	0,75	1,20
95% lower conf. Limits	*2,11*	*2,83*
95% upper conf. Limits	*3,46*	*4,55*

The *Omnibus test of normality* accepted normality in the Oxie sample but rejected normality in the Toarp sample. Test of equal variance was positive and was necessary prior to running the Mann-Whitney test. A hypothesis was set forth to test the equality in the samples:

Ho: Toarp = Oxie, Ha: Toarp ≠ Oxie

The decision level was 0,05 to accept equality of median. Following results were received after running Modified-Levene equal variance test, Mann-Whitney/ Wilcoxon test (table 5).

Table 5: Population test of the samples from Oxie and Toarp.

Test method	Test value	Prob. Level	Decision (0,05)
Omnibus test of normality- Toarp	6,495	0,039	Reject normality
Omnibus test of normality- Oxie	3,3416	0,188	Cannot reject normality
Modified-Levene equal variance test	1,6759	0,212	Accept eqal var.
Mann-Whitney/ Wilcoxon test	1,4751	0,140	Accept Ho *

*Hypothesis; Ho: Toarp = Oxie, Ha: Toarp ≠ Oxie

The statistical results from the non-parametric tests indicate that the samples do not differ from each other. The box plot graph (figure 2) can be used to support this further.

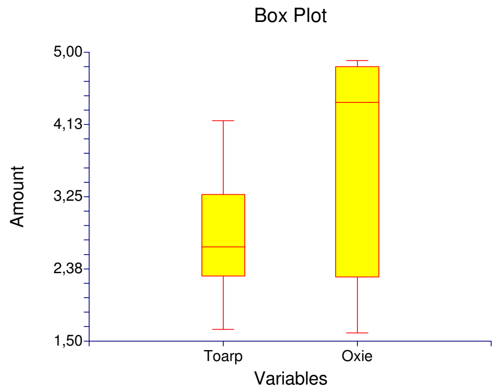

Figure 2: Box plot showing the span of observation in Toarp and Oxie.

It can be concluded that both samples originate from the same population. If we combine both samples into one pool and calculate the average the result is 3,2 ha/person/year.

4.2.2 Comparison on educational and professional background

Educational and professional background was compared between the towns and the results are displayed in table 6. No significant difference in educational level or profession was observed. The number of children in Toarp is considerably greater (19) than in Oxie (9) but does not seem to determine completely what kinds of background people have.

Table 6: Educational and professional background in Toarp and Oxie.

	Toarp	Oxie
Educational background	number of answers	
Compulsory school		
high school	8	8
College/ University of technology	3	2
University	3	2
Profession		
Accounting/finance	1	1
Consulting	1	
Governmental sector	3	2
Manufacturing/production/operations	2	3
Research and development		
Computer related	3	2
Engineering	2	3
Legal services		
Medical services	7	2
Sales/ marketing	1	3
Unemployed	1	1
Pensioner		1

*Two households did not fill in this category.

4.2.3 Graphical display of the footprint values

The following two figures reveal which categories of the household consumption differ in both villages. Figure 5 shows how and on what kind of land categories the consumption is spread.

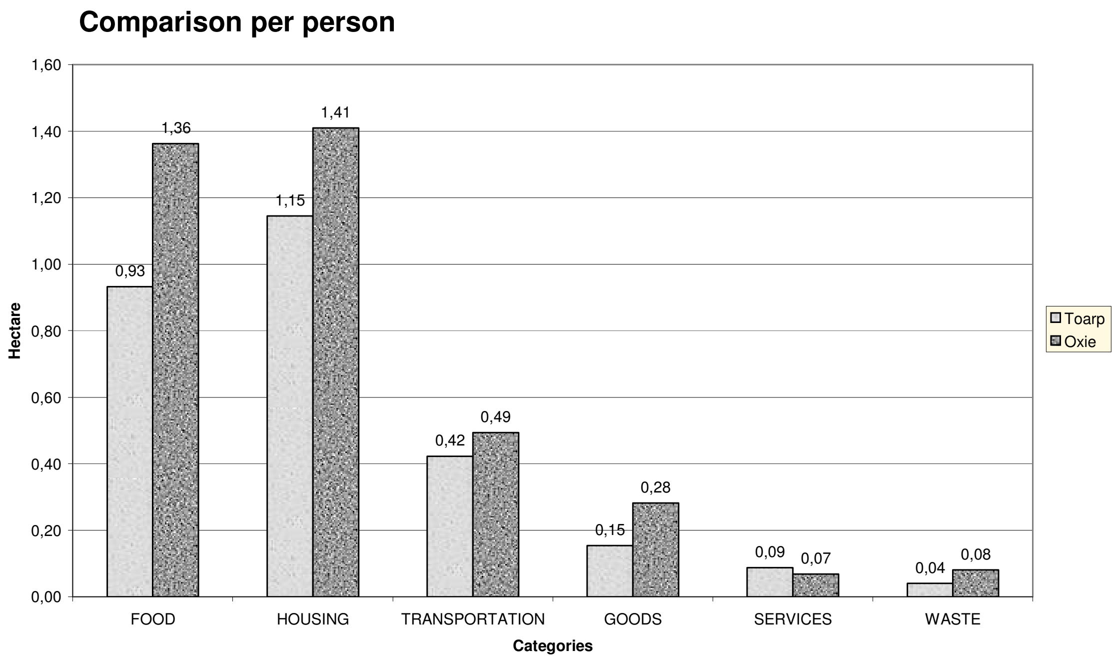

Figure 3: The average footprint in hectare **per person** from each consumption category in both villages.

Comparison per person in figure 3 reveals smaller footprint in Toarp than in Oxie.

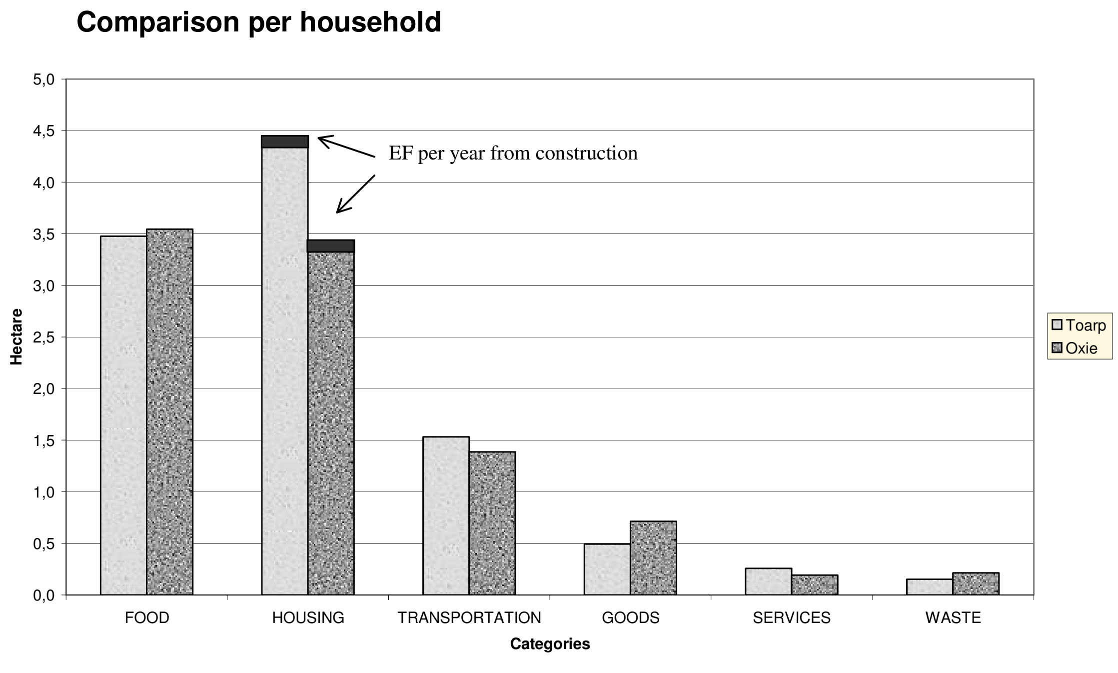

Figure 4: Footprint in hectare **per household** is compared between the villages.

In figure 3 it is observed that the largest difference between the two villages lies in the food category. Oxie has ~30% larger footprint in food *per person* than residents in Toarp. The footprint in the housing category is ~18% lower in Toarp than Oxie. The category goods, transport and waste are little higher in Oxie. If we compare the footprint *per household* (figure 4) the difference is only marginal in all categories except for housing. There, Toarp has ~20% larger footprint than Oxie. Other categories do not show much difference. The embodied ecological footprint from construction is included as black box on top of the housing columns (0,16 hectare per year over 50 year period).

The footprint assessment is divided into six categories, fossil land, arable land, pasture land, forest, build-up land and sea space (see chapter 9.3 for further explanation) When we compare the land used in Toarp and Oxie we observe large difference in the *fossil and forest* categories (see figure 5).

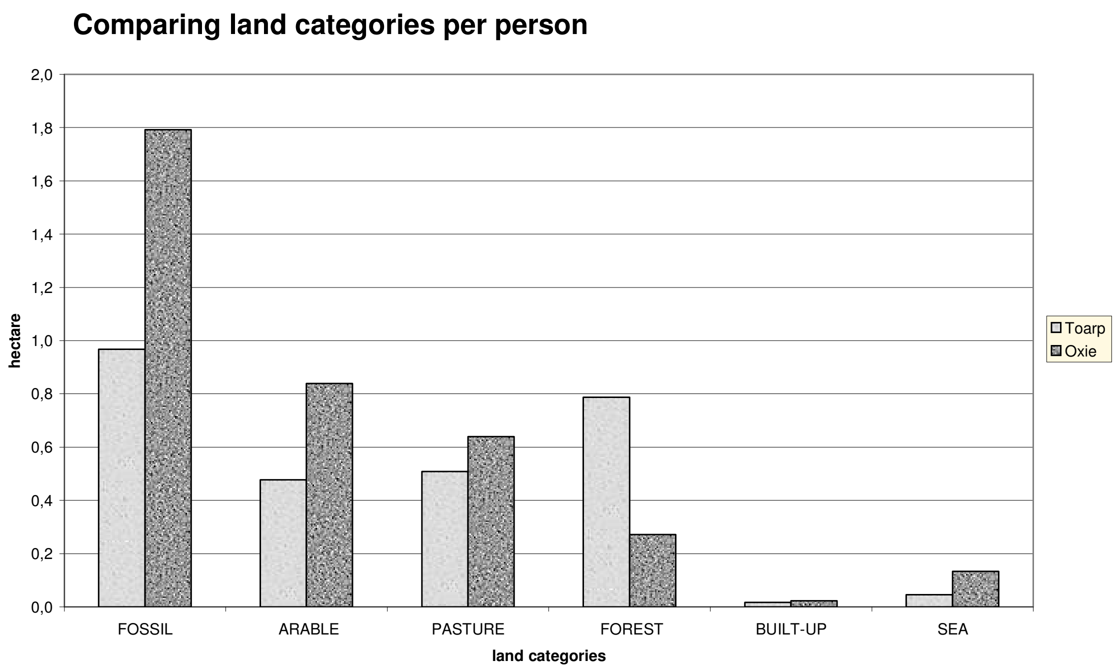

Figure 5: The footprint per person is allocated on different land categories.

If the average footprint value from both samples is subtracted from the national value of 5,9 ha, we can obtain the footprint value from the governmental and industry sector. In this study it is 2,7 ha (if the 1993 data set is used). The footprint of the governmental sector is in the form of social welfare (schools, hospitals etc.), national defences, administration and infrastructure. The footprint from the industry comes from import and export of raw materials, production etc.

The next chapter will identify possibilities to reduce the footprint of the Swedish households and the governmental sector, as well as the industry.

4.3 Simulations of the Swedish footprint

This section will simulate the Swedish footprint and compare it to available footprint globally. The study focuses on trend in development of footprint in an average Swedish household and for total Sweden. Following simulation graph shows scenarios run from the year 1900 to 2080. The scenarios presented here, all run from the year 2000 and onwards. Following are the proportions each household category contributes to the total national footprint:

- The housing sector contributes 21.7%
- The food sector contributes 19.4%
- The transport sector contributes 7.8%

- The goods sector contributes 3.7%
- Other household sectors contribute 2,3%
- *The governmental/industry sector contributes ~45%*

Table 7 presents the average value calculated from Toarp and Oxie. The mean value was used to simulate the Swedish footprint. The details of the model are available in Appendix II and formulas in Appendix III.

Table 7: Potentials for decreasing the ecological footprint in households

Toarp and Oxie combined			
	Mean EF value	Decrease of EF	Final EF
Food	1,15	0,57	0,57
Housing	1,28	1,15	0,13
Transport	0,46	0,37	0,09
Goods	0,22	0,11	0,11
Services	0,08	0,04	0,04
Waste	0,06	0,03	0,03
Total ha	**3,24**	**2,27**	**0,97**

The table 7 shows what potential exists in decreasing the footprint in the household sector if; consumption is decreased by 50% (services, goods, waste), communal transport is chosen instead of private car which reduces impact by. ~80% and for the housing, reduce footprint by 90% (known as factor 10).

4.3.2 Graphical display of scenarios

Following six scenarios demonstrate possible outcomes by carrying out different strategies.

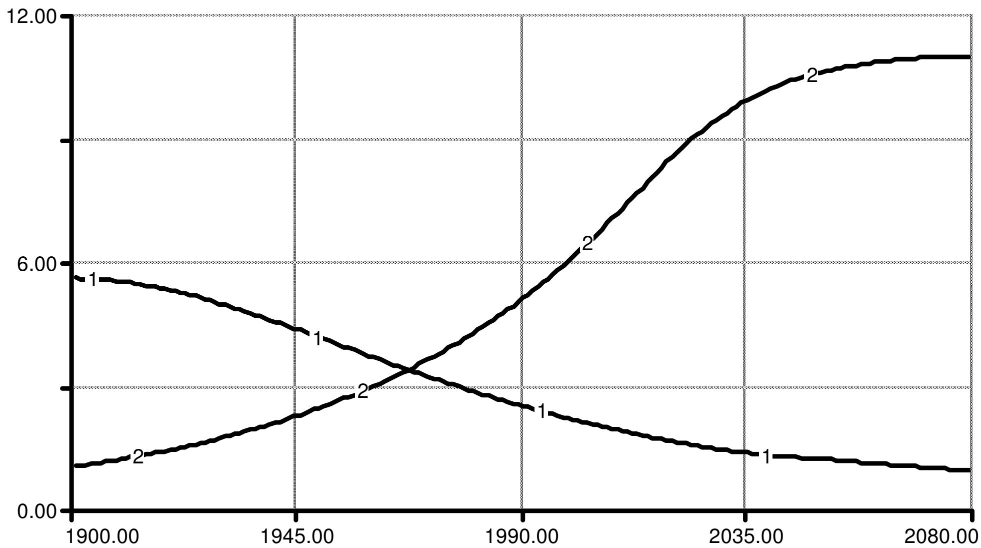

Figure 6: ***Scenario 1- No changes.*** It is assumed that footprints cannot increase forever, thus when the global available footprints per capita decreases in the next century, the general consumption will also reach some upper limits (line 2). The footprint is assumed to have S-shaped behaviour. The global share of footprint (fair Earthshare) is expected to shrink from 2.2 ha in 1998 to 1.2 ha in 2050 and 0.9 in 2080 (line 1).

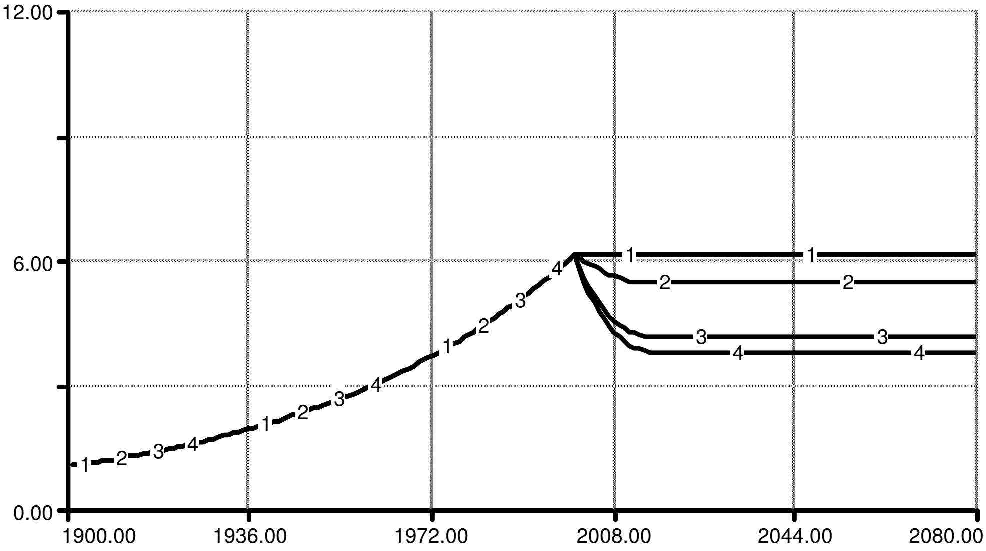

Figure 7: ***Scenario 2- Reduction potentials in households.*** This diagram presents what potentials there are for decreasing the footprint. ***Line 1*** shows the footprint level as it is today. ***Line 2*** shows the footprint level after reducing meat consumption in households by 50%. ***Line 3*** shows potential in reducing footprint in housing, by implementing factor 10 and reduction of meat consumption by 50%. ***Line 4***, includes all above and demonstrates as well reduction in transport, services, goods and waste by 50%.

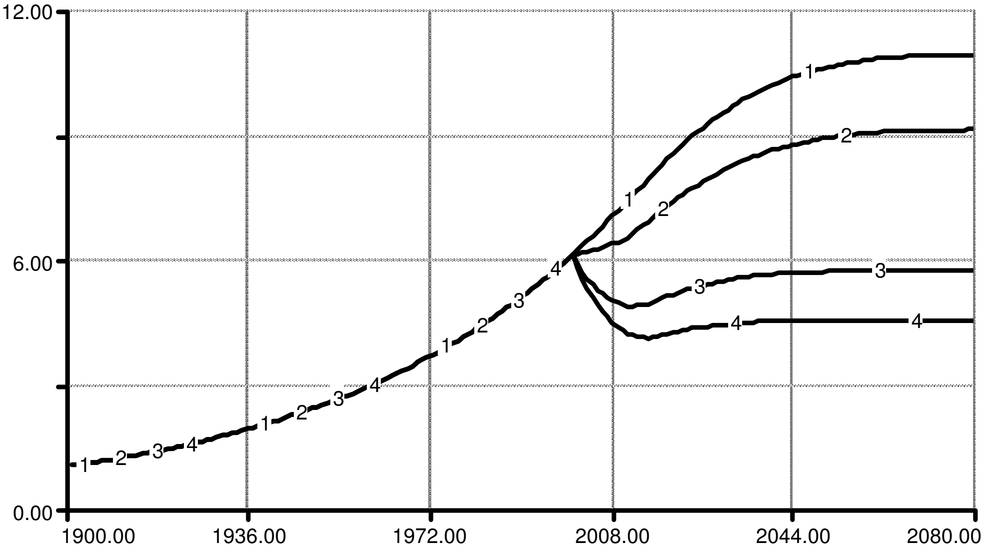

Figure 8: ***Scenario 3- Household scenario.*** Different implementation strategies are tried for households. ***Line 1,*** is unchanged scenario. ***Line 2*** is 50% decrease in meat consumption over a fifteen-year period. In scenario ***Line 3***, same as no 2 but also the energy use in the housing sector is decreased by 90% over a fifteen-year period. ***Line 4***, factor 10 is implemented in housing and food consumption is decreased, plus additionally is the mean of transport changed to more communal one, services and consumption of goods changed so it decreases its footprint by 50%. This could lead to some 70% of total decrease in footprint per capita for households. The graph shows proportional reduction in the footprint per category households, it is assumed that the governmental/ industry sector is passive towards any actions.

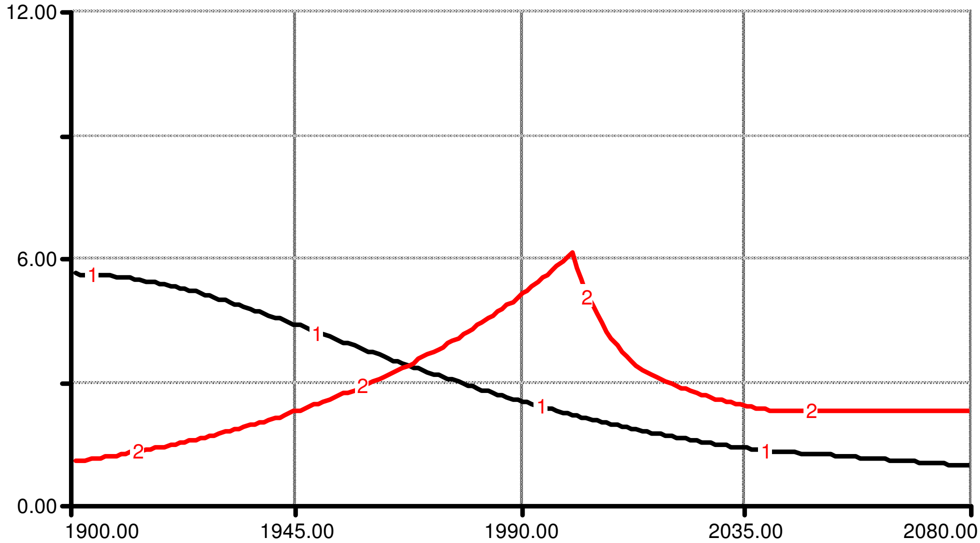

Figure 9: ***Scenario 4- Governmental, industry 50% and household, 70%.*** In addition to the energy and consumption savings made by the households (total 70%), the governmental and industrial sector reduces its footprint by 50% These changes are stretched on a time period of 40 years. Note that the Swedish national level (***line 2***) is 2.2 hectare per person, but is still above the *fair Earthshare*, which is expected to be 0.9 hectare per person in 2080 (***line 1***).

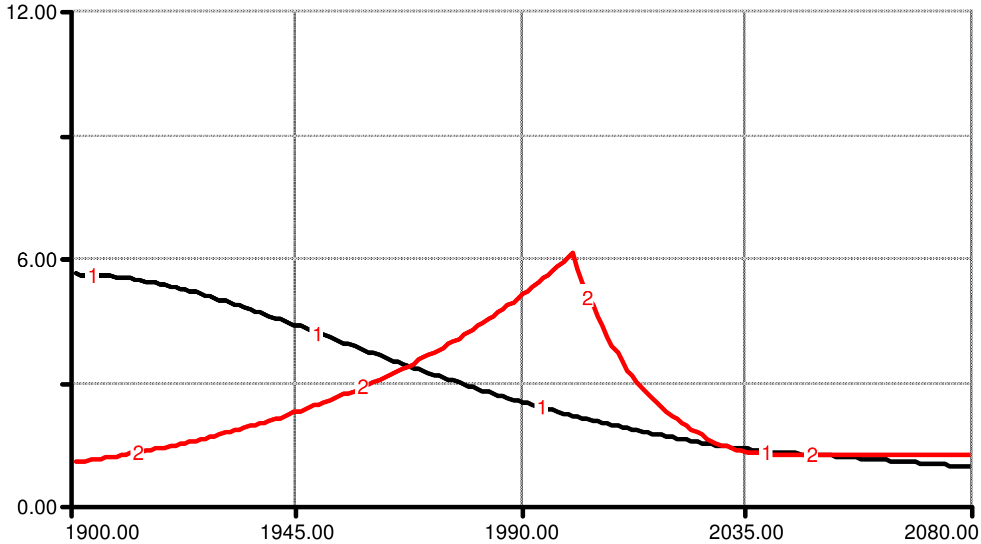

Figure 11: ***Scenario 5- Government, industry 90% and household 70%.*** In the idealistic scenario, the governmental and the industry sector implements factor 10 policy which would lead to reduction of footprint by 90%. This scenario will reduce the over all footprint of Sweden by 85% and probably only possible if major changes are made in the society. These changes run over 40-year period (***line 2***). Although this scheme is carried out, it does not become sustainable in the long run, since the *fair Earthshare* falls below the Swedish national footprint due to world population increase and environmental degradation (***line 1***).

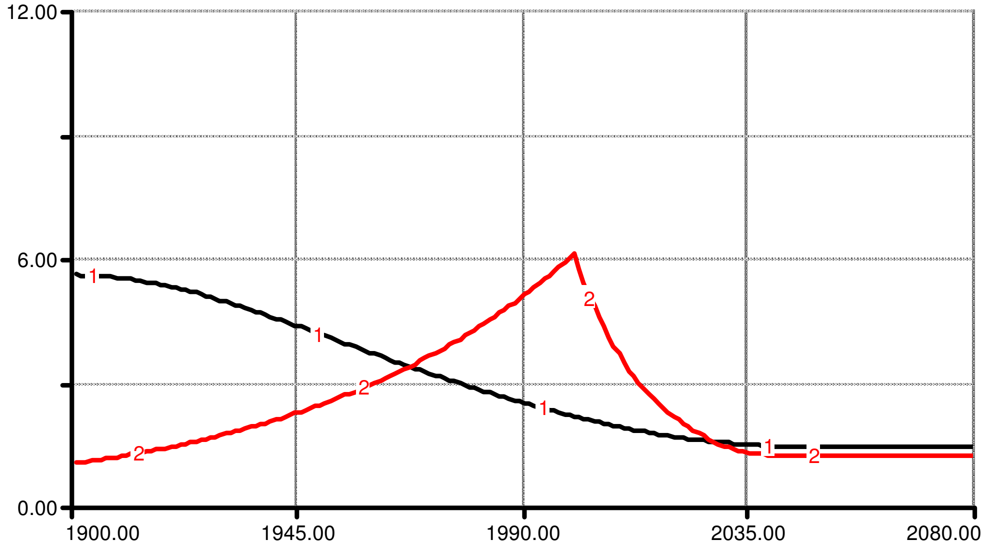

Figure 11: ***Scenario 6- Sustainable Sweden.*** This is the same as scenario 5. But if we assume that in the year 2000 global environmental degradation will be reversed for the first time, the global share of footprint will decrease at slower pace. Since the population is increasing so rapidly, there is still ~1 % annual decrease in the fair Earthshare until the year 2050 by which the global population is assumed to stabilise. If Sweden manages to decrease current footprint levels by 85% (90% in governmental and 70% in the household sector) over the next 40 years and the international community manages to reverse environmental degradation in the same period, Sweden can have footprint value that is below the fair Earthshare and become ecological sustainable. This scenario also includes 12% ecological space set aside for biodiversity, which was proposed by the Bruntland commission (0,25 hectare per person by the year 2000). The final values are the following: *fair Earthshare* 1.4 hectare per person, the Swedish footprint 1.1 hectare per person. ***Line 1***: *fair Earthshare*, ***Line 2***: Swedish national footprint.

5.0 Discussion

This chapter discusses results from the analysis of the construction phase of houses in Toarp and Oxie, results of the footprint analysis of households in Toarp and Oxie and simulation of the Swedish national footprint.

5.1 Comments on the construction analysis

The study on the building materials covers the 10 most common material used in conventional constructions. According to Berge (1992) the total energy needed to construct 100m^2 house is between 360 and 540 kWh/m^2 in Scandinavian climate. The results from the energy calculations in this study fall well within Berge's definition (Toarp house 403 kWh/m^2 and standard house 509 kWh/m^2). What differ between the conventional house and the eco-house are the quantities of several materials. The largest difference and perhaps the most important one is the quantities of plastic used in the standard house. The difference in embodied energy per m^2 between the two houses is 106 kWh/m^2, which is virtually the same as the embodied energy per m^2 in use of plastics in a standard house (see table 1). Some materials are used in larger quantities in the eco-house, such as bricks and expanded clay blocks, but the total embodied energy in the building materials is still 20% lower than in the standard house. Since plastic materials are so energy intensive they increase the total energy needed to construct the standard house.

The calculated emission rates are 1 ton higher in the standard house than in the eco-house (see table 1). This difference can mainly be allocated to the production of plastics. Since the transport distance was assumed to be same, the emission from the transport was 3 tons per house.

Only 10% difference is between the standard house and the eco-house after converting the total construction energy value to the corresponding ha footprint. Once again, this difference can be allocated to the plastic materials used in the standard house.

Although the lifecycle inventory covered only 10 building materials and just energy and CO_2 emissions, the results fall well within Berge (1992) definition on energy intensity in housing construction. It can be concluded that the results are fairly accurate in describing the total energy intensity through conventional building process.

According to Heino & Bruno (1996) the average lifetime of a building is 50 years before being subjected to major maintenance. Since the difference in the two construction methods is so little, the total energy put in the construction phase is small compared to the energy needed for lightning and space heating. In the Toarp and Oxie examples, the energy need per year for space heating and lightning is on average 1.28 hectare, which means 64 hectare per house in 50-year period. The construction phase contributes only ~8 hectare through its lifetime, which is 12,5% of the housing footprint (see figure 4) If it is compared to the total household consumption, the construction phase is less than 5% of the household footprint. This could indicate that more attention should be focused on saving the running costs rather than building costs.

Since building ecologically is rather a recent event in Sweden, it has been more expensive than conventional methods. Much of this extra expenditure has been allocated on "green" technology such as local water and waste management, greenhouses and technical aspects of the buildings (Lundbeck, 1991). This has led to projects being abandoned or fitted within a certain economical frame. The concentration has been focused on how to keep things affordable and still build ecologically. According to Lundbeck (1991), projects that are ecologically oriented have not been supported financially by the government like other conventional building projects. Since most community housing projects are tenancy right oriented, they have to be attractive for possible dwellers. In that case there is a limit to what extent housing projects may cost. This could explain to some part why there is currently so marginal difference between ecological and conventional building processes.

New methods are always costly to begin with especially if they are more technologically oriented. For example using a wind generator to provide electricity for the housing could increase the total building costs substantially but decrease the footprint value of the housing by several factors. Regardless if the building is more ecological oriented or not.

5.2 Comments on the footprint analysis

The study of the ecological footprint analysis in Toarp and Oxie revealed the following:

In the sample from Toarp, 39 people share the consumption in 10 households, which corresponds to *~102* ha footprints per year if all inhabitants share the footprint evenly. In the sample from Oxie, 30 people share the consumption in 10 households, which corresponds to ~*94* ha footprints per year if all inhabitants share the footprint evenly. This implies that an average household in Toarp has consumption corresponding to *10,2* hectares per year whereas in Oxie the average is *9,4* hectares per household. It is important to understand that the footprint of any household depends totally on the *number* of inhabitants partaking in the consumption. This means calculation of averages needs to be done carefully, not to even out the numbers. A household of 6 people consumes little more efficiently than household of 2 people since the housing and transport e.g. do not change that much with different number of dwellers. As a result form individual households, the average footprint per person in Toarp was 2.8 hectare per year and 3.7 hectare per person per year in Oxie.

Statistical comparison reveals no difference between the two samples. But since the sample sizes include only 10 observations in each place, it is hard to conclude with certainty that there is a difference. The range of observations is much larger in Oxie than in Toarp (see box plot in figure 2). Toarp has on the other hand tighter range of values although extremes in both places are about the same. Further study with much larger sample sizes could certainly change these values and probably give more secure range of data. Since no statistical difference was recognisable between the two samples the mean value 3.2-hectare per person is allocated for both samples. In this study, this value represents the household footprint in Sweden and is used for the simulation purposes.

It is often stated that people who choose to live in eco-village are more educated and more environmentally engaged (Lundbeck, 1991). Table 6 shows very little difference in professional and academic background between Toarp and Oxie. There seems to be rather even distribution between the two places regarding what people do and what academic background people have. There are on the other hand more children per families in Toarp than in Oxie (Toarp: 20 adults, 19 children, in Oxie: 20 adults, 10 children).

The food category: When we look at the consumption categories ***per person*** in Toarp and Oxie we observe that food and housing represent by far the largest footprint (figure 3). In Toarp it counts for ~74% of the total footprint and in Oxie ~75% of the total footprint. It clearly indicates which factors are most contributing to the ecological footprint. If we look at figure 3, we can observe considerable difference in the food category. This difference was analysed and did not show dissimilar kind of diets or any considerable differences in quantity of food between the households, as one would suspect. The factor that determines the difference, is the number of people in the households. Toarp has on average almost one more individual per household than Oxie. The footprint methodology does not distinguish between adults or infants. A large family of 6 individuals shares the total footprint of the household, there is no adjustments made for e.g. one child equals ½ adult, etc. This is because the national footprint value is calculated using the total population, regardless to age groups in the country. A large family of six people would benefit from the footprint assessment since infants consume much less food than adults, but are at the same time included in the assessment of other household categories. The second factor that might have influenced the food category is the quantity of food per person. Although people in Toarp consumed little less per person than in Oxie, this difference was only 2% in terms of footprints (see food category in figure 4).

The footprint of food consumption is largely allocated on arable land and pasture. It can be observed that the food-footprint per person in Toarp is smaller due to more people per household (see figure 5).

The housing category: The housing category reveals ~18% difference between the villages when we look at the footprint ***per person*** (figure 3). Although the houses in Toarp use between 50-70% less electricity than their counter parts in Oxie, they still have greater footprint. Apart from having solar-collectors and heat exchangers, the houses in Toarp are also equipped with wood stoves. Annually, the average wood consumption ***per household*** is $10m^3$ per year in Toarp. This consumption increases the footprint of the households by ~23% compared to Oxie (see housing category in figure 4). The allocation of the footprint is well demonstrated in figure 5, where Oxie is more dependant on *fossil land* for energy supply as Toarp uses more *forest land* for energy supply (see chapter 9.3 for explanation on footprint calculations). One could ask why wood consumption creates larger impact than electricity production. The answer is that, hydro and nuclear electricity produced in Sweden is more productive per hectare per year than average forests productivity (see chapter 9.3.3 for further explanations). Since more people are residing per household in Toarp this consumption does not show in the comparison per person.

Other categories: The transport, goods, services and waste categories represent only ~25% of the total footprint in both villages. As before if the footprint is compared **per household** in both places, the difference is marginal although transport is little higher in Toarp. That could be explained by larger number of commuter in Toarp (39 Toarp *compared to* 30 Oxie). The "goods" category is higher in Oxie, which could in some way reflect materialistic lifestyle but it is hard to evaluate such things from the data set. Services and waste show marginal differences between the villages per household. If we consider the same numbers in **per person**, the footprint in Toarp becomes considerable lower in almost all categories. Greater number of people in Toarp again explains this difference.

In figure 5 there are two categories that are interesting, the fossil land and the forest land categories. The forest land category is the only category were Toarp has higher footprint value than Oxie. Most of this footprint is allocated to space heating in the Toarp households. The reason for almost double higher footprint in the fossil land is the space heating and electricity use in Oxie. In both households, transport is mainly allocated on fossil land. In Oxie transport is 27% of the fossil land category and in Toarp the transport is 43% respectively.

What is to be learned form the comparison previously discussed are the following facts: the most important consumption categories are the food and housing categories. They amount for roughly 75% of the total footprint in both Toarp and Oxie. Although transport is a large factor in the household, it contributes only ~14% to the total footprint. As observed in the Toarp sample, one fact can be considered, more people per household decrease the total footprint per person. This is important because it indicates that large houses that are only resided by 2 persons is very inefficient in terms of footprints. It would be recommendable to either use renewable energy sources or increase efficiency, or increase dweller per m^2 house. Since we consume food today which requires great amount of energy in processing, it is hard to reduce the footprint without completely stop consuming certain types of products.

How much does the household footprint contribute compared to the rest of the national footprint? In a study, currently conducted by Wackernagel, *et al.* (1998d), the 1994 statistical data from Sweden is used, which is considered more accurate than the UN-data set from 1993. The latest calculates for the Swedish footprint is 7,2 hectare per person per year compared to 5.9 hectare in the 1993 data set. If we compare the household data set with the latest update on the Swedish footprint from 1994, following results are obtained (see figure 12).

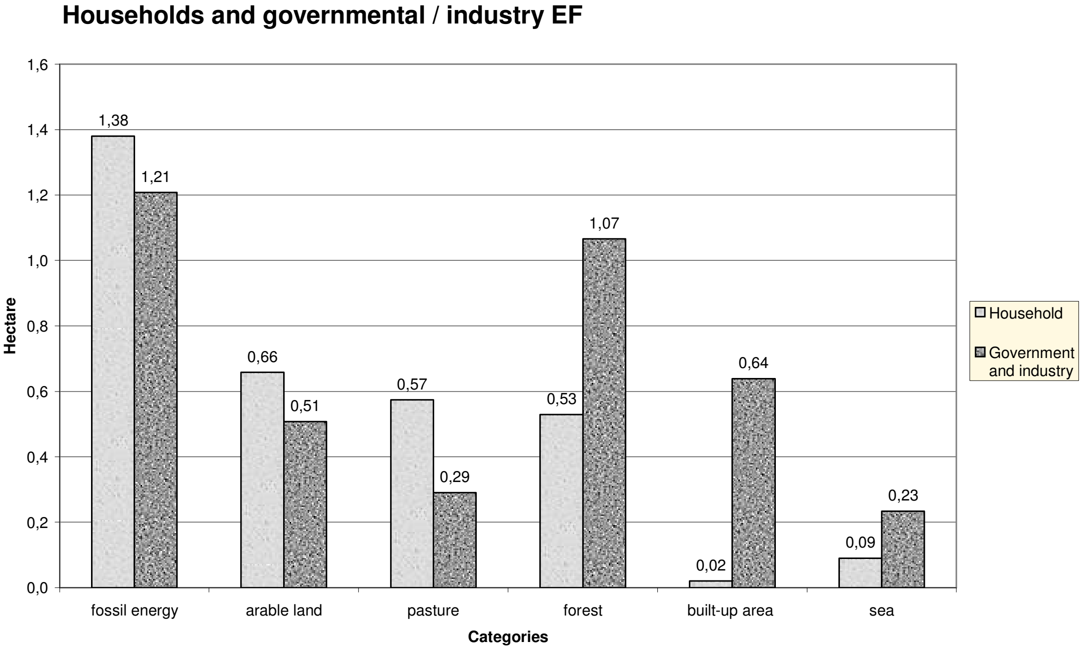

Figure 12: The household footprint is compared with the national footprint value (Wackernagel, *et al.* 1998d).

The difference between the household and national value is the footprint allocated to the governmental and industry sector. No study has been conducted in Sweden, which allocates the proportions between the governmental and the industry sector. Since the Swedish welfare system is rather extensive, it can be assumed that the governmental body contributes to a fairly large part of the footprint. It could be as much as 40-50% but further research is needed before any real assumptions can be taken.

What can be read from figure 12 is the following: The governmental/industry sector (GI) has its largest footprint in fossil energy, forest land and build-up land. If we look at the build-up land, it represents all buildings, roads and bridges etc built in Sweden. It can be argued that the governmental part is larger in this case since it is involved in many construction projects. In the *forest and sea-space* categories the industry is probably the largest contributor. Other GI categories follow certain trend with the household categories (see graph 12). If we make the assumption that the GI footprint has the same proportions per categories as in the households, it becomes possible to estimate how large different consumption categories are. In table 8, the Swedish footprint data from 1994 has been fitted to have the same distribution as households.

Table 8: Assumed allocations of the State/industry (GI) footprint.

	EF in ha households	EF in ha* State/industry	A- assumed footprint in ha	*EF %*	B- assumed footprint in ha	*EF %*
FOOD	1,15	0,94	2,09	*29*	1,98	*28*
HOUSING	1,28	1,98	3,26	*45*	2,81	*39*
TRANSPORTATION	0,46	0,64	1,10	***15***	1,65	***23***
GOODS	0,23	0,24	0,46	*6*	0,46	*6*
SERVICES	0,08	0,07	0,15	*2*	0,15	*2*
WASTE	0,06	0,09	0,14	*2*	0,14	*2*
EF total	*3,25*	*3,95*	*7,20*		*7,20*	

*** Assumed allocation if the EF of the State/industry has the distribution as the household sector**
A- Swedish national EF, the state/industry has the same footprint distribution as the household sector
B- Same as number A but ~80% of the total fossil energy in the state/industry sector is allocated to transport

Two scenarios can be read from this table, in scenario A, the distribution is the same as in household. In scenario B, 80% of fossil energy is allocated to transport. Even if we assume that ~80% of the fossil energy is in transport, it would be no more than 23% of the total national footprint. The food and housing categories in this assumption are between 67-74% of the total national footprint (see table 8). Further research is needed before any definitive conclusions can be made on the size of the GI footprint, which is beyond the scope of this study.

The conclusions from the EF assessment indicate that housing (space heating and electricity use) and food consumption is the most important factors that contribute to the Swedish footprint per capita. If any attempts are to be made to decrease the ecological footprint of Sweden, the solutions should be oriented towards housing and food consumption.

5.3 Comments on the simulation

Simulating the footprint can give policy makers a chance to test policies and where to concentrate in reducing the Swedish national footprint. The six scenarios in chapter 4.3.2 show the potentials that exist to decrease the Swedish national footprint per capita in the 21 century. The results show that *if Sweden manages to decrease current footprint levels by 85% over the next 40 years and the international community reverses environmental degradation in the same period, Sweden can have footprint value that is below the fair Earthshare and become ecological sustainable.* This can be accomplished if the governmental/industry sector implement factor ten policy and households reduce its footprint by 70% through improved housing and change in consumption pattern.

What are the limitations and what can be learned form the modelling? Regarding footprint predictions, it is hard to estimate consumption patterns in the society far ahead in the future. What the model shows is the current development of the footprint and how it could develop if the Swedish society would develop towards an American lifestyle. External changes such as environmental disaster, war and etc are not included in the modelling. Such changes would surly change the development of the footprint. In that sense the model is very plain and static. According to Meadow *et al.* (1992) and Brown (1997) the world is moving from resource abundance towards a world of scarcity. The only important matter is how we are going to share these scarce resources (Wackernagel, & Rees, 1996).

It is likely that the Swedish footprint will not develop to 11-12 hectare per capita. Actually such discussion is irrelevant to the modelling purposes, since the model shows the potentials in decrease of the Swedish footprint. If Sweden will develop high consumer economy like the Americans, it will be much harder to reduce the footprint than if a lover economic development course is taken. In that sense the model can be used to predict certain scenarios as done in figure 23, which can partially be used to predict certain assumptions. For instance, in the model it is assumed that the footprint of the food category in the Swedish *households* can be decreased 50% by reducing meat consumption. The scenario indicates that this factor does not affect the total national footprint as much as believed but allows us to distinguish better between different footprint contributors. Food products are high energy demanding and claim over 30% of the total energy used in a typical industrial country: 10% of this energy is consumed by agriculture, and the rest, 90% is used in preparation, packaging, transport, etc (Heilig, 1993). By reducing meat consumption, arable land is freed up for other purposes and energy can be saved. Cereals production is more efficient than meat production and requires only around 1/5 land area per footprint unit (Wackernagel & Rees, 1996, Cowel & Clift, 1996).

This brings us to the arguments of energy and externalities. Since the environmental degradation is not yet included in the consumer price, consumers do not feel the need for changes. Since energy use is one of the largest contributors to the Swedish footprint, it should be a priority thing to be addressed. Generally in western countries, energy (especially electricity) is so heavily subsidised by the government that the consumer never pays the right price for the energy but does it through other taxes in the society (Lovins, *in Miller 1996*). According to Johansson *et al.* (1993), taxes and regulations should ensure that consumer decisions are based on the full cost of the energy, both environmental and other external costs not reflected in marked prices. This should stimulate efficiency in the society and more growth in the use of renewable resources (Johansson, *et al.* 1993). Today efficiency in the use of energy is only fraction of what is thermodynamically possible. It is not unrealistic to decrease energy use on a large scale, in fact Lovins (1996) estimates that the world economy could save as much as 1$

trillion per year if energy efficiency became a serious issue (Lovins, *in Miller, 1996*). Decreasing the footprint has a lot to do with saving energy, which can be clearly observed in the housing categories in Toarp and Oxie.

5.3.1 Ecological living in Toarp and Sweden

This thesis sought to answer the question if ecological living as defined in Sweden is more sustainable than conventional living? If Toarp represents an average eco-village profile in Sweden, this study answers the question "no". Statistically there is no difference between the two observation places in the household comparison and only 10% difference in the comparison of building materials. But Toarp has smaller average footprint per person, due to larger family sizes per household. Thus the more people there are per household the smaller the footprint becomes. This was observed in Toarp and in some households in Oxie. According to Wiberg (1998) dwellings in apartment houses are usually smaller and the space heating is somewhat more efficient per person. If households from a newly built apartment house would partake in a comparison study with Toarp, it is likely that conventional lifestyle could reveal even less footprint than Toarp.

Toarp differs from Oxie in several ways; it has its own biological waste purification (root-zone) and composting toilets, and its own well for drinking water. It is hard to estimate directly to what extent these factors contribute to the footprint. For example the root-zone system is virtually non-mechanical and has very low maintenance compared to conventional water and sewage systems. Conventional systems are on the other hand costly to maintain and construct but can be the only viable solution in dense urban areas (VA-Verket, 1998). The social factor in eco-villages is undoubtedly important and as Lindén (1997) points out, there are more tendencies in eco-villages to shift from individual family centred lifestyle towards more co-operations in a broader group. This could give eco-villages some advances in promoting environmental awareness among the inhabitants.

What can be considered the most important factors in ecological living? The largest contributors to the ecological footprint in households are the housing and the food categories. The attention should thus be focused on these two categories. For instance, if permaculture (permanent-agriculture) would be seriously considered in eco-villages, as Folke (1995b) suggests, the energy savings in the local food production could be as much as 80% compared to the conventional lifestyle. This would certainly reduce the footprint of Toarp if implemented. Toarp has good potentials to become more sustainable (in terms of footprint), by concentrating on local energy production (wind energy) and shifting food consumption towards more vegetarian food and local production.

Another issue can also be brought up in Sweden, should we continue to build eco-villages or should we focus on improving the existing housings? Since the energy consumption is so large part of the household footprint, it would seem more practical to focus on improving existing housings. According to Wiberg, (1998) the restoration costs of fitting old houses with eco-efficient technology is roughly the half compared to building a new conventional house. But Wiberg (1998) further comments that building ecologically is more expensive than conventional building if all ecological technologies are included such as waste treatment, solar panels etc, which make building entrepreneurs think twice before starting such projects. It is here where policy makers play an important role. Alternative energy provided by wind power and solar energy is more expensive than energy provided by present utility companies. But if the price for decommissioning the nuclear power and storing the nuclear waste were included the scenario would certainly change. According to Lönnaeus (1998) and Sydsvenskan (1998) this hidden cost is around 4,5 billion dollars. As discussed in previous chapter, policy makers have the choice between subsidising existing energy system or subsidising energy efficient systems and renewable energy technologies. The experiences obtained from the ecological villages in Sweden give valuable learning experience and will surly help promote such changes. Ecological living should not just be adopted in certain type of villages but in the whole society as well. Ecological living has to be integrated in all aspects of society. Radical changes as such are undoubtedly on of the greatest issues that determine the path towards sustainable future.

In figure 24, it is explained that ecological lifestyle has to be prompted by a reason and a change in Society and economical policies. Like Daly (1993) suggests, changing fundamental attitudes in economical policies towards steady state economy will lead to more sustainable practices and undoubtedly stimulate ecological living. Reducing and reusing resources will without any doubt be the most prominent challenge for the next century.

6.0 General conclusion

This study sought to answer the question if ecological living is different from conventional living in Sweden. The study concludes that "no" difference exists in the ecological footprint between the ecological living and the conventional living in the form as presented today. Following conclusions where made from the comparison:

- The ecological footprint analysis on building materials used in an eco-house from Toarp and a normal south-Swedish house reveals only 10% difference. Building materials represent less than 5% of the total annual footprint per household in Toarp and Oxie.
- The ecological footprint analysis on consumption between Toarp and Oxie shows no statistical difference in the ecological footprint *per person*. Toarp has footprint 2.8 hectare per person per year and Oxie has footprint 3.7 hectare per person per year.
- Food consumption and energy use for housing (space heating and electricity use) are the largest contributor to the footprint in Toarp and Oxie. These factors are almost equal in size and constitute 75% of the total footprint in both Toarp and Oxie.

There is no significant difference in the ecological footprint *per household* between Toarp and Oxie. The difference in the ecological footprint between the two places is related to the number of people per household. Toarp has 3.9 persons per household and Oxie has 3 persons per household. This difference lowers the average footprint for Toarp.

Simulating the footprint can give policy makers a chance to test policies and where to concentrate in reducing the Swedish national footprint. The total ecological footprint of Sweden is 5.9 hectare per person per year. Households in Sweden contribute on average 3.2 hectare (55%) per person annually to the total national footprint. The governmental sector and industry contribute 2.7 hectare (45%) per person annually to the total national footprint. The *fair Earthshare* of biological productive land per person is currently 2.2 hectare per capita, but is expected to decrease to 1.2 hectare per capita in 2050. Ecological sustainability can be defined as being below the *fair Earthshare*. If Sweden reduces its footprint by 85% over the next 40 years it can achieve national footprint value that is below the *fair Earthshare*. To do so, following policies need to be implemented:

- The households need to reduce its ecological footprint by ~70%
- The governmental and industry sector needs to reduce its ecological footprint by ~90%

More research is needed to determine what factors in the governmental and industry sector contribute most to the footprint. It would undoubtedly increase the accuracy of the footprint predictions and clarify quantitatively where the most attentions are needed to reach sustainability.

Appendix I:

7.0 Background to environmental problems

This chapter will review some historical aspects of how environmental awareness has evolved. The chapter will discuss the link that exists between the economy and ecology and in conclusion will discuss the early views and emerging efforts towards sustainability.

7.1 The start of environmental awareness

The Swedish chemist Arneus (Miller, 1997) pointed out in 1896 that increased CO_2 in the atmosphere could lead to global warming. He was one of the first scholars to make correlation between human actions and environmental changes. Some researchers that followed pointed out various forms of degradation and pollution in the environment but little attention was to it throughout the first half of the twentieth century. For the last 40 years the attitude towards the environment has changed gradually. It has evolved according to the focus on the environmental problems. The focus has changed from 'being a local' problem to a problem shared globally (Miller, 1996).

The sixties marked the beginning of a world-wide official recognition of environmental problems. In that period the pollution problems in the western societies where becoming so compelling that many scientists started systematically drawing public attention to them. Silent Spring written by Carson (1962), is perhaps one of the most prominent books on the subject. Although it was focused on pesticides and chemicals, it brought forth the intention of their use and obvious examples of their consequences. The industrial society had over the years used many forms of chemicals in industrial and agricultural production. These were not only harming local ecosystems, but also finding their way up the food chain and into human food consumption. These chemicals, according to Carson, where used universally and intensively with insignificant thought about the consequences (Nelissen *et al.* 1997). Unlike other books on similar context, Silent Spring was a wake up call. People observed the effects of pollution in their nearest surroundings. Everyone was unintentionally contributing to the problems, the government, the industry and the consumer. This eventually led the US congress to form a committee on environmental affairs to tackle the problem. Increased public awareness marked the beginning of the environmental movement, which few years later played an important role to motivate the industry and planners towards environmental thinking.

7.2 The link between economy and ecology

In recent years the discussion about sustainability has been as much about how the concept itself should be defined, as to finding possible ways to achieve it. Ever since the "Brundtland commission" published its report in 1987, scientists from different academic institutions have debated how serious the state of the environment is, and what methods are most feasible to tackle the problem. Lack of shared background and acknowledgement of environmental problems have lead to conflicts between different groups who see their economical existence threatened. Experts with common or different background argue for different solutions that are as much destructive as constructive. A good example is the "global warming" debate, which has prompted lively discussions on development in general. Research at large has become more closely tied to policy questions such as, how or when do we need to respond to environmental problems, or which action or delay is most provident. Hempel (1996) argues that the complexity of today's political- and economical system call into question the capability of ordinary citizen to grasp the overall perception on environmental problems and what action to take against it. As a consequence, the next century may well demonstrate whether modern science and politics can be reconciled in democratic governance (Hempel, 1996).

In today's society none is left untouched by the globalisation of the economy. Liberalisation of international trade has increased the flow of services and materials globally. It has made the concept of local markets obscure as products become more internationally fabricated and shipped world-wide. In western societies there has been a strong tradition for measuring welfare of nations in expansion of the economy. Gross National Product (GNP) measures the national output and is generally known as an indicator of economic growth. Increase in growth leads to increase in resource use and waste production. The throughput in the economy is almost equal to the GNP, and can be defined as the cost of maintaining final goods and services by continuously importing high quality matter and energy from the environment and exporting low quality heat and waste back into the environment (Daly, H. 1993). Traditional economics portray the economy as closed and linear system with limited or no link to the environment (see figure 13).

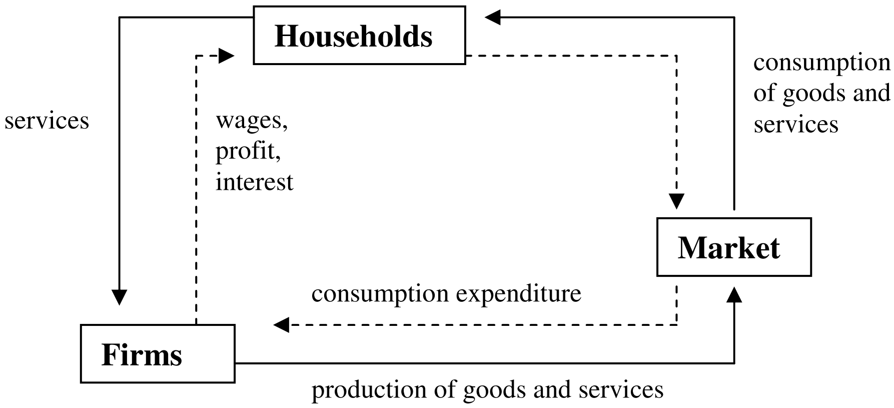

Figure 13: Simplified representation of economic reality. This is how traditional economics have proceeded in making models of society. This economic system is portrayed as self-contained and thus independent from the ecosphere (Turner, *et al.* 1994).

In reality this is impossible since the economy is physically constrained by the ecological foundations it is based on. The economy is an open system that must extract, process and discharge large amounts of materials and is only able to do so because of the support of its ecological foundations (see figure 14) (Turner, *et al.* 1994). As a consequence the natural environment is the limiting factor both to waste assimilation and resource availability (Turner, *et al.* 1994). Some environmental economists, suchlike Herman Daly (1993) have stressed the need to develop a steady state economy.

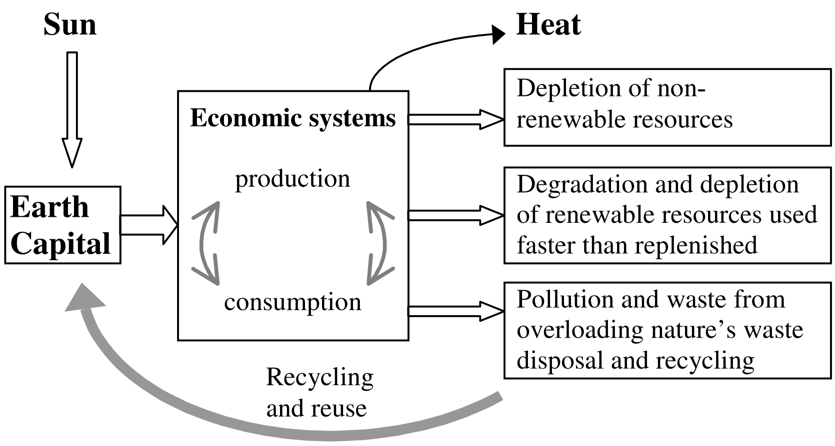

Figure 14: Environmentalists see all economies as dependant on resources and services provided by the Sun (Miller, 1996).

Steady state economy does not maximise throughput but tries to maintain stocks of essential items (Daly, H., 1993). The need to develop steady state, Daly (1993) argues, comes not only on account of physical constrains of the environment, but also because of social and moral limitations. Since GNP does not include the depletion and degradation of natural resources or measures quality of life, economists have looked for other alternatives, which combine these factors into one index. Indicators such as Net National Product (NNP) or the Index of Sustainable Economic Welfare (ISEW) adjust the GNP by including depletion or destruction of resources, long-term environmental damage and income distribution (Miller, 1996).

7.3 Economy and complexity

Tragedy of the Commons by G. Harding (1968) and the *Limits to growth* by D. Meadow (1972) are examples where the authors tried to show how unrestricted consumption on natural resources could adversely affect the global society. These theories became well recognised by many scientists and popular among the public, but met strong opposition from the mainstream economists. One of them, Julian Simon, became well known for down playing all "doomsday" predictions by stating that no problem existed with population growth or with unsustainable use of resources (Simons, J. *In* Miller, 1997). According to Simons, people are the ultimate resource, who through their productiveness and inventive minds constantly creates new resources. In supporting his ideas, he used mortality rate and life expectancy as an argument against common ideas on overpopulation. He pointed out that the prices of food, metals and other raw materials have been declining for the last 50 years, and at the same time, become less scarce. Simon further stated that problems encountered in the beginning of the industrial age enhanced creativity and pushed nations such as England to develop appropriate technology to deal with wood scarcity. This resource crisis eventually lead to the coal based economy (Simons, J. *In*. Miller, 1996).

Simons's statements can be true as long as flow of material and wastes goes unaffected in the economy and is not restricted by external factors. Tainter (1996) and Norde (1997) on the other hand state that development of complexity is one of the most important factors of societal and economical development. In their view, the energy is the fundamental factor that determines how societies evolve since the whole economy is dependant on it. With relative easily accessible energy, societies can grow large and as they do so, complexity increases. Complexity refers to things such as the size of the society and the variety of specialised roles it has, also the number and distinctiveness of its parts. The larger the society gets the greater its complexity becomes (Tainter, 1996, Norde, 1997). Tainter (1996) further argues that the economy is a process, which leads inevitably to development of greater complexity. The changes are usually in form of further specialisation of the governmental body. As societies increase and face larger problems, the problem solving strategy used, leads in many cases, to an even more complex society. But increased complexity and specialisation come at the cost of benefits. Tainter (1996) explains further;

> *"...If our efforts to understand and resolve such matters as global change involve increasing political, technological, economic, and scientific complexity, as it seems they will, then the availability of energy per capita will be a constraining factor. To increase complexity on the basis of static or declining energy supplies would require lowering the standard of living throughout the world." (Tainter, 1996, p10)*

The use of fossil fuels has made it possible to ignore easily the benefit/cost ratio of social investments and has been sustainable for several generations since industrial societies could afford it. Historical societies such as the Roman Empire are important examples (see figure 15) of how increasing complexity in the economy will experience diminishing returns. Tainter (1996) comments further:

> *Most actions that the Roman government took in response to crises-such as debasing the currency, raising taxes, expanding the army, and conscripting labor-were practical solutions to immediate problems. .... Cumulatively, however, these practical steps made the empire ever weaker, as the capital stock (agricultural land and peasants) was depleted through taxation and conscription. Over time, devising practical solutions drove the Roman Empire into diminishing, then negative, returns to complexity.(Tainter, 1996, p8).*

Since the society was dependant on solar-based energy and was heavily taxed, the empire had little fiscal reserve, which made it vulnerable to external changes. England was confronted with similar scenario before the industrial age. As population increased around 1300 and 1600 the agriculture and industry intensified. The major fuel source, the wood was becoming scarce and could no longer meet the needs of heating, cooking and manufacturing. New alternatives had to be developed. Since coal was fairly abundant in England at that time it was an excellent option, which could replace wood as major fuel source. Coal was also a better fuel source but was much costlier to obtain. As the coal gained more importance in the economy easily accessible resources became scarce, new technology had to be developed to obtain it. A whole new and more complex industry was developed which led to the industrialisation (Tainter, 1996).

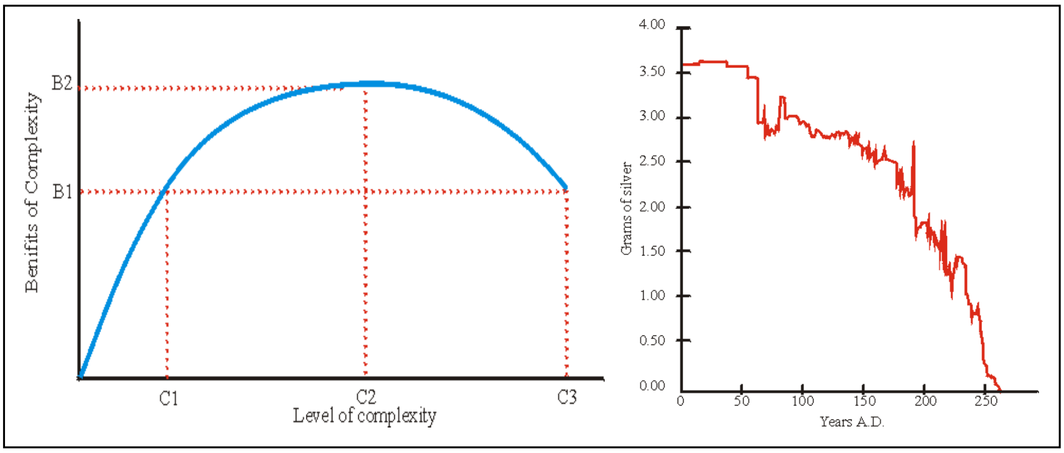

Figure 15: The development of complexity in historic societies. Tainter (1996) has pointed out three phases at which the benefits from becoming complex are the most at the beginning but decrease and eventually become negative with increasing complexity. Societies can solve their problems by becoming more complex (picture left) and increase their benefits, but as complexity increases the society will experience diminishing returns to the point of negative returns (C3). Responding to diminishing returns (picture right), the Roman Empire debased its currency by reducing the silver content in the coin. Large amount of worthless coins were produced as a respond to depleted reserves (Tainter, 1996).

This scenario can be regarded as typical for the industrialisation in Europe and worked since the resources were fairly abundant. What can be regarded as similar when comparing the ancient societies and today's world, is the problem solving strategy. In our societies, we tend to tackle the problems by investing in more research and expand governmental bodies. This becomes clear when we look at environmental problems and how we tend to solve them today. Tainter (1996) interestingly explains this;

> *"...investments (in environmental problems) will be costly, and may require an increasing share of each nation's gross domestic product. With diminishing returns to problem solving, addressing environmental issues in our conventional way means that more resources will have to be allocated to science, engineering, and government. In the absence of high economic growth this would require at least a temporary decline in the standard of living, as people would have comparatively less to spend on food, housing, clothing, medical care, transportation, and entertainment. (Tainter, 1996, p9).*

This argument plainly displays the conflicts that exist between goals of economical development and the goals of sustainability. Few people would accept decreasing their living standards for something that "might" help solving the environmental problems and people are likely to stay that way as long as the understanding of the interconnections between ecosystems and the society is missing.

7.4 Reviewing environmental problems and defining sustainability

Until the sixties, the general notion was that technology improvements could fix problems of human existence. Technology in theory and the global surface area provided the only limitation to population growth. Population growth became one of the main themes in the late sixties as to explain the causes of environmental degradation. Biologists often used their discipline to explain behaviour of the society. Paul Ehrlich for example, tried in his book, *The Population Bomb*, to explain through a Darwinist and Malthusian approach how the law of diminishing returns and the survival of the fittest could be applied to explain how overpopulation and the level of food production could be altered. Ehrlich stressed the needs for increase in food production and at the same time the importance of implementing birth control in the underdeveloped countries. His book became popular in the west since it gave strong arguments towards safeguarding the Western way of life but blamed the third world countries for creating a overpopulated world (Nelissen, *et al.* 1997). Although Ehrlich's publication is a rather outdated attempt to address population problems it put the issue on a political level and stimulated further studies (Nelissen, *et al.* 1997). The topic of overpopulation has directed researchers more to the scope of carrying capacity of ecosystems and its correlation to human consumption.

Perhaps the most influential work over the last two decades is the study *The limits to growth* done by D. Meadow in 1972. Meadow with help from Jay Forrester, created a dynamic computer simulation that predicted collapse of the society due to over-consumption and disruption of ecosystems (see figure 16). This was a dramatic argument that met hard criticism from scientists and economists around the world. Meadow and his team was criticised heavily for too many assumptions about the level of fossil- and natural reserves in the world and the model could not possibly describe reactions of all relevant variables in the world (Nelissen, *et al.* 1997). Some argued that technology could be used to minimise pollution or more efficient technology could be developed to minimise the effects. Nevertheless *The limits to growth* put the ecosystems restrictions at the centre of the political debate (Nelissen, *et al.* 1997).

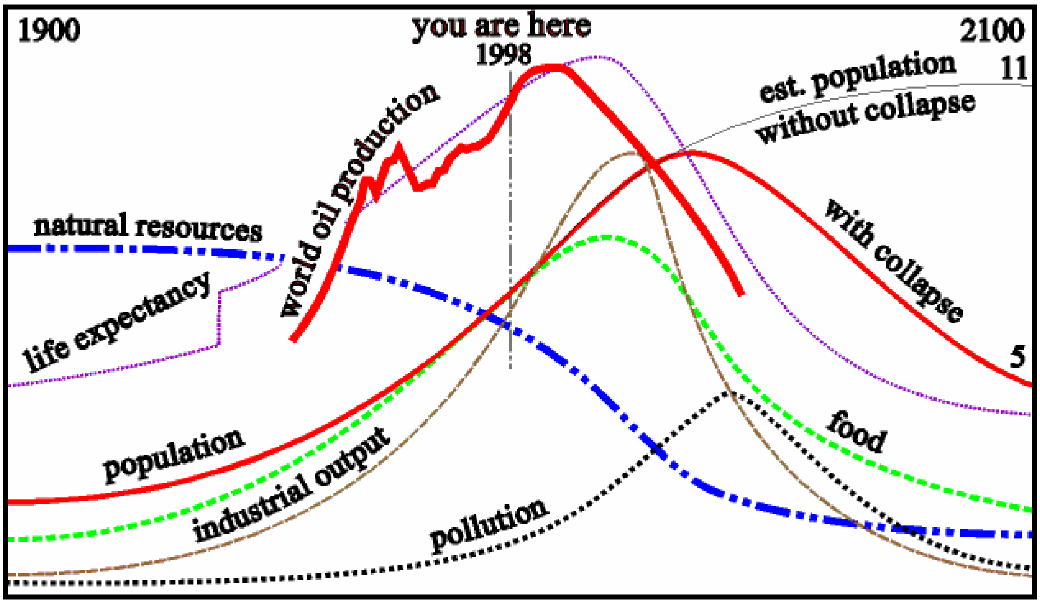

Figure 16: Simulation of the world. This model is an improved version of the study done by Meadow in 1972 but it demonstrates basically the same scenario as the original one (Meadow, 1992, p.133, World oil: Duncan & Youngquist, 1997 *In* Hansson, J. 1998).

Another scholar E. Goldsmith (1972) wrote in *"A blueprint for survival"* that continuous population growth posed increased ecological demand on a finite natural capital. Similar prediction where made in the US governmental report *"Global 2000"*. Population was supposed to stabilise at 30 billion at the end of the 21-century, which was hypothesised to correspond to the maximum carrying capacity of the Earth (Nelissen *et al.* 1997). The *Global 2000* report was pessimistic in its prediction but stimulated massive debate between economists and natural scientist and raised public awareness about overpopulation and unstable ecosystems (Nelissen *et al.* 1997, Miller, 1996). Since the sixties, several studies have been conducted to address questions on carrying capacity and material flow, each focusing on different aspects such as energy requirements, non- and renewable resources or photosynthetic potential. They all share the important common principle of tracing resource and energy flows through the human economy (Wackernagel & Rees, 1996).

7.3 Current definition on sustainability

Since human trade and transactions are international, economical activities stretch the whole globe. On a daily basis Individuals do not perceive that their environment is deteriorating. Further more, large sections of the population are just beginning to see the impact of their own actions and consumption patterns. Due to these complex interactions, the environmental problem is seen as deep-rooted in the society. It sparked two major world conferences, one in Stockholm 1972 and the other twenty years later in Rio. The Earth summit in Rio 1992, like the Stockholm summit, was expected to give a common ground internationally on how to reverse environmental degradation and construct an environmentally sound future (Hempel, 1996).

With the publication of *Our Common Future*, the terminology *sustainable development*, became a widespread concept and ever since the summit in Rio 1992, it has progressively become the slogan for environmental awareness. Its primary expression *"…to meet the needs of the present generation without compromising the ability of future generations to meet their own needs"* has become popular both by the public and in the industry sector. Although criticised by many environmental organisations, the summit provided a common starting point for nations (Hempel, 1996). The well acceptance of the *sustainable development* concept comes from its vague definition and non-quantification on how to reach sustainability. Gibbs and Hooper (1996) explain that even though sustainable development has been implemented at all levels of policy making in many countries it still lacks common ground on to what degree intervention should come. Elaborating further the authors say;

> *"…Many policy-makers have agreed that sustainable development must form the basis of future economic policy, even if they are also vague as to what it means and how to achieve it."(Gibbs & Hooper, 1996, p79)*

This has resulted in various different definitions on sustainable development and often a distinction is made between "strong" and "weak" sustainability. "Weak" sustainability advocating for higher priority in economic policy, and "strong" sustainability requiring targets to be set from an environmental perspective in such a way that the whole economy is affected (Gibbs & Hooper, 1996, Pugh, C. 1996). Most problems today are considered as local and are through international laws regulated to individual countries. According to Andersson (*et al.* 1995) many more environmental problems should be regarded as trans-boundary and as a global threat in the long run. The fact that they are only treated as local comes from the lack of understanding and knowledge of the complex interactions between the society and ecosystems.

7.4 Environmental paradigms

According to Capra (1997), rapid population growth, environmental degradation and resource scarcity have led to social disorder in local communities throughout many parts of the world in the post Cold-War era. These problems can be seen as merely different sides of a one single crisis, which is mostly a crisis of perception (Capra, 1997). Capra explains this further by saying:

> *"...It (the crisis) derives from the fact that most of us, and especially our large social institutions, subscribe to the concepts of an outdated worldview, a perception of reality inadequate for dealing with our overpopulated, globally interconnected world." (Capra, 1997, p4).*

Two fundamental views can be distinguished as major environmental thoughts, Shallow-ecology and Deep-ecology. Shallow-Ecology is human centred or an anthropocentric view. It considers humans as the source of all value and above nature, and ascribes only instrumental value to nature (Capra, 1997). Deep-Ecology on the other hand views humans as just a strand in the vast web of life and recognises the intrinsic value of all living beings. In Deep-Ecology everything is interconnected and nothing is separated form the natural environment, including human beings (Capra, 1997). According to Malbert (1996), better understanding of social issues and different environmental paradigm can be more constructive and make it easier for the general public to follow the debate. Arne Naess (1989 *In* Malbert, 1994) describes five different environmental policy paradigms, which he clarifies as current world view on development. These five paradigms are listed as; *frontier economics, environmental protection, resource management, eco-development and deep ecology* (see table 9).

Table 9. Different environmental paradigms that relate to the current policy debate (adapted from Naess 1989, In Malbert, 1994, p12)

View of nature	View of social development
Frontier economy: Nature's value is linked directly to the human potential to utilise resources that are in principle considered to be unlimited.	This presupposes economic growth and increased use of resources. The continued build-up of industrial society with the expansion of urban centres is desirable and non-problematic.
Environmental protection: The same as above but with a greater focus on human health and well-being. The negative effects of mankind's use of resources should, if possible, be limited.	Similar to frontier economics but acknowledges the need for a certain degree of control to balance exploitation and protection interests. Urban environmental problems can be solved through technical development.
Resource management Acknowledges resource and pollution crises as a limiting factor on human activities. The Brundtland Commission's "sustainable development" (1987) subscribes to this view, which also includes protection of endangered species.	This view is relatively technocratic. Continued economic growth is presupposed although within the framework dictated by nature. Urban development should be controlled by demand for energy and resource management. This is achieved through more efficient use of resources, an ecocycle approach, technical development and restrictions on exploitation.
Eco-development: Nature has its own intrinsic value alongside its value to mankind. The interest in preservation does not apply exclusively to endangered species but rather to the whole ecosystem.	The ecocycle approach and management demands are the same as in resource management but are not as technically oriented. All development should take place within the framework dictated by nature. The holistic view and integrated solutions, which also include social systems, should be strived for and achieved. Urban ecosystems should be strengthened. Technical development adapted to nature is a precondition for satisfying ecological and social goals.
Deep ecology: The human being is part of nature. In principle, human activities should not take place at the expense of other living beings.	Economic and material growth in our part of the world is undesirable. There is a good deal of scepticism towards large cities and complex technical systems. All human activities should be arranged in natural cycles and ecosystems. Winding down and dismantling large-scale systems is desirable.

How can sustainability be defined in quantifying terms? Since humans as species cannot be excluded from carrying capacity of ecosystems, the same can be said about the economy. Human societies as other populations in the natural environment can be placed under following definition (Miller, 1996);

> *"... the maximum population of a particular species that a given habitat can support over a given period of time..." (Miller 1996, A43).*

Several studies have been made which use the natural capital as a starting point and defines how much is available of non- and renewable resources for human consumption. The Environmental Space (ES) and The Ecological Footprint (EF) are the methodologies that are most well known. Both methodologies define flow of energy, matter and waste by a given economy, and convert these into corresponding units required from nature to support these flows. The Ecological Footprint for instance, accounts for flow of energy and material to and from any economy and converts these into the corresponding land/water area needed from nature to support these flows (Wackernagel & Rees, 1996). If we use the natural capital as a starting point for sustainability, then defining the concept becomes very simple and basic:

> *"...to secure people's quality of life within the means of nature"(Wackernagel & Rees, 1996, p2)*

Extracting no more from nature than can be replenished becomes very important element. It requires a shift in perception from the conventional view of how to manage resources and waste, to managing ourselves. This can be related to the existing attitude towards technology, where the fundamental perception is to develop "fail save" systems. Much rather should the approach be reversed and the focus put on "save fail" technology, which allows technology to fail without large environmental consequences. The nuclear power program is a typical example of the "fail save" approach which has not lived up to its "fail save" standards (Chernobyl and Three Mile Island). Still this issue is heavily debated in the western countries.

When the energy and the material flow of the economy are directly related to the ecosystems, it brings a totally new dimension to the discussions of sustainability. The concept "weak" sustainability is harder to lobby for when sustainability can be quantified and measured directly.

7.5 Cities and sustainability

Since ancient times people have been attracted to live in cities. By Martinotti's (1997) definition, a city is a "transformer" in the sense that food, raw material and energy are altered into social activities, cultural artefacts and products. There is a common feature that can be recognised in ancient urbanisation centres. They usually consisted of double systems that consisted of an inner circle and outer circle. The inner circle was made up of villages, which produced the food and partially the manpower. The outer circle constituted of small colonies, which collected and traded raw material that was not available close by such as wood, minerals, gems etc (Martinotti, 1997). Every link was a vital contributor to "sustain" the flow of material in and out of the city. A city or a society was able to sustain itself as long as the material and waste flowed freely through it. According to Ponting (1991) cities played a very small role in the lives of most people in the past. Less than 2.5% of the world inhabitants lived in cities before the 18^{th} century and truly urbanised cities as we recognise them today emerged as a result from the industrialisation. Urbanisation is expected to reach the level of 50% around the year 2010 (Martinotti, 1997).

Today's cities are just like the ancient cities, they depend on distant sources for their food, energy and raw materials. Because of their massive use of recourses they damage nearby and distant ecosystems. This makes very few cities sustainable (Miller, 1997). A normal US city with 1 million inhabitants uses materials very inefficiently and generates large amounts of waste (see figure 17).

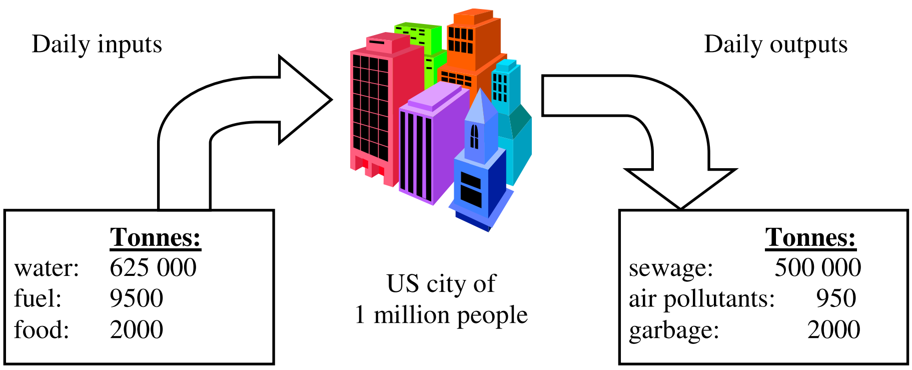

Figure 17: Matter and energy are constantly transferred in and out of a city. Cities have become dependant on distant sources for their food, water, energy and materials. The figure shows values for a typical US city of 1 million inhabitants (Miller, 1997).

For inhabitants in a large city it is easy to forget how fragile the city is and how dependant it is on the distant ecosystems. According to White (1992), each individual is dependant on specific areas of the world to support their lifestyles. White (1992) further elaborates by stating:

> *"...These support areas may be invisible form the perspective of an individual city- dweller, but they are highly visible on earth satellite photographs as new or more productive farmlands, diminished forest areas, or oil and gas fields on land or on continental shelves" (White, 1992, p.9)*

Much has been debated on how to reach sustainability within cities and what it means to be sustained. For many people it has to do with sustaining human activities, such as economic growth, jobs or political stability. Other consider that sustainability in cities has to do with combination of meeting people's needs and the commitment to sustaining the natural capital (Mitlin *et al.* 1996). According to Rees (1992, *In* Mitlin, *et al.* 1996) the total land area required to sustain a city can be considered at least ten times larger than the city's own boundaries. All cities depend on the carrying capacity of other areas through global trade and natural flow of goods and services (Rees, 1992, *In* Mitlin, *et al.* 1996). For example, Wackernagel & Rees (1996) calculated the area of land needed to support the Netherlands economy. They looked at four categories of domestic consumption; *food, forest products, fossil energy* and *build-up land*. The results were that the calculated area needed to sustain this part of the Dutch economy was fifteen times larger than the country's territory. According to Wackernagel & Rees (1996) lifestyle is an important factor which determines the ecological needs of countries.

In recent years efficiency has become a more and more important factor in the industrial sector. Not only strive businesses towards efficiency in their management and production but also in environmental performance. Due to increasing environmental awareness the industry has shifted its focus towards reduction of material use and recycling. Many regard efficiency in the industry as top priority for the sustainable development. According to Bleek (1995) less than 20% of all material that is extracted from the environment end up in products and infrastructure. Concepts such as eco-efficiency, factor 10 and de-materialisation are all common goals to reduce the impact the society has on nature (Bleek, 1995). Some regard lifestyle changes even more important than eco-efficiency and stress the importance of living ecologically by consuming less (Wackernagel & Rees, 1996, Miller, 1996). In recent years attention has been progressively paid to design of more resource- and energy efficient dwellings. These buildings have become known as eco-buildings, and living in them, as ecological living.

8.0 Ecological living

Discussion on energy efficiency, pollution, consumption, etc has prompted lively debate on how to implement actions toward sustainable development on practical level. Cities can become more environmentally and economically self-sufficient. Sustainable or ecological city (eco-city, green city, eco-village) differs form conventional city in such a way that it uses resources and energy more efficiently, minimises harmful emissions and decreases waste production through recycling (Pugh, 1996).

The principal idea with ecological living is self-sufficiency. It involves a change in lifestyle from being a total receiver of resources towards production and recycling of resources. People living ecologically extract their own water, produce their own food and energy and other materials needed for self-sustainment. Gunther (1989) identifies three key parameters that separate conventional living from eco-living;

1. Dwellings are super insulated and designed to use resource efficient technology.
2. Localised agriculture meets the basic food needs for the inhabitants.
3. Energy is collected locally and all waste material is recycled.

To keep the nutrient balance in the soil, all refuse and solid waste is biologically treated and recycled. No chemical imported fertilisers are used in the growing vegetables etc. In eco-city, people are dependant on a specified land area that is used for their sustainment and this land area is usually not larger than the city area. The design of eco-city is made in such a way that distances to important localities are accessible by foot or biking. An eco-town is the "peoples city" in which the social factor is regarded as an important factor for the development and planning of the city (Boverket, 1991, Gunther, 1989, Malbert, 1994, Miller, 1996).

Folke Gunther (1989, 1995a) argues that communities based on ecological living concept must be much smaller than normal urban areas. He suggests that these communities should not exceed the number of 200 inhabitants (Gunther, 1995a). The arguments used here are that strong social connections can build between the inhabitants in smaller communities. If there is fairly age distribution in the town it gives possibilities for some elderly to engage into more local social responsibilities such as childcare etc. Such local services decreases the pressure on elderly care at national level but creates much more security and responsibleness for seniors (Gunther, 1989). Gunther further argues that if ecological communities are to function well, they have to be able to decide totally by themselves what is to be done in the community in matters like, transport arrangements, production etc.

8.1 The Swedish definition of eco- villages

The Swedish Housing Ministry (Boverket, 1991) defines ecological living and ecological villages an area with apartment houses that use efficient technology to create and maintain as much self-sufficiency as possible. Energy use should be as low as possible and produced by renewable energy systems. The houses must be healthy and free from all allergy-producing materials (Boverket, 1991). The Swedish Housing Ministry put forth 12 points that are considered important for definition of an eco-community (see table 10).

Table 10: Wiberg and Persson have listed 12 points in which they define ecological living (Boverket, 1991).

1. Every housing unit should have access to land area for home-grown vegetables.
2. There should be an access to cool storage place that is not energy dependant.
3. Drinking water should be taken from a local well.
4. Toilet should be separated form effluent water and all wastewater should be handled locally.
5. Solid waste should be recycled and organic waste composted for local use.
6. Rainwater should not go into the sewage-system.
7. Eco-houses should not be build on slopes that have their gradient from north-east to north-west , or be placed where more than 25% of the sunrays are blocked. Building should be wind protected.
8. Energy use for space heating should not exceed 50 kWh/m^2 annually and heating of household water should be from renewable sources.
9. Where possible, electricity should be produced from wind-power and electrical instruments should be as energy efficient as possible.
10. Limited mechanical or non-mechanical methods should be used for ventilation.
11. Building materials should have informative label and be non-allergic producing. Building designers should consider the risk of mould build-up and try to avoid it.
12. Community locals should be appointed in which all inhabitants have access to.

Malbert (1994) emphasises that ecological planning, building and management is a pedagogical challenge, which is perhaps greater than the technological challenge. Resource management is a vital challenge that needs to be included in changes and new planning. The existing settlements and infrastructure are an important resources, which should be continued to use in the future, and long-term sustainable relationship should be developed between the urban areas and the rural area. In Malbert's view resource management and eco-cycle approach bring new dimensions into the ecological planning (Malbert, 1994).

Through the nineties the concept "factor 10" and the MIPS (Mass Intensity per Unit of Service) have been developed as a mean for the industry and communal sector to estimate material flow and how to dematerialise and reduce its energy use by 90%. According to Bleek (1997), reducing the material use in the economy is important to reduce total flow of energy. Today the material flow "cradle to grave" of most common materials in the economy is very inefficient since only 20% of the total material set in motion ends up in products and infrastructure (Bleek, 1995). Many researchers and environmentalists believe that increasing efficiency, dematerialization and reducing consumption are vital factors towards sustainable future. In general, it can be said that ecological- living is about carrying capacity. Just like the farmer who always had to assess the grazing capabilities of his land, human beings have to become aware of their ecological dependence. The following chapter will discuss a few methodologies, which are used today for environmental assessment.

9.0 Environmental methodologies used in the study

This chapter will focus on the environmental methodologies used in this research, which are; the lifecycle assessment methodology (LCA) and the Ecological Footprint (EF). The environmental impact assessment (EIA) will also be discussed here since it is often used parallel with LCA.

Although many different assessment methodologies have been emerging in recent years, none are as popular as the EIA approach and the LCA practise. Arguable, the popularity of these tools can be related to the flexibility of the procedure in the assessment process that can be related to data uncertainty. Environmental impact assessments often incorporate lifecycle studies and are used by policy makers and project developers to either favour, disprove or redirect certain planning procedure.

9.1 The Environmental Impact Assessment

In the sixties the concept Environmental Impact Assessment (EIA) appeared in the US. It was developed as a response to political pressure from environmental lobbying and introduced as a new planning technique through the National Environmental Policy Act (NEPA). It was required in all federal funded or supported programs, which were likely to create environmental impact (Weston, 1997).

EIA is a study that analyses the affects of procedure of industry and industrialisation on the physical environment and on society. Although several procedures are well recognised and accepted in carrying out physical environmental assessment, societal impact assessment is more difficult, and rarely takes into consideration broad socio-economic factors, since it follows more complex dynamics. This in turn leads to more value based assessment and individual judgement, which can be tricky especially in the third world (Porteous, 1996). Although EIA has been practised for the last 40 years there is still no precise definition that can fully explain its role in environmental management. According to Weston (1997), the EIA can be described as a process that can recognise possible consequences of implementing certain activities and conveying that information to those who are responsible for implementing them. Further elaborating on this, Weston states;

> *EIA is a process having the ultimate objective of providing decision-makers with an indication of the likely consequences of their actions (Weston, 1997, p4).*

What made EIA different from earlier planning procedures was that it brought a more holistic approach to the planning process. The ecosystem became an important indicator in the evaluation procedure and for the project development as a whole. The EIA has developed into an overall assessment tool. In the developed countries EIA has been legalised as a standard procedure to be integrated into major planning process. What makes EIA particularly vulnerable is lack of data, especially when planning in the undeveloped countries, where often the largest projects are taking place (Porteous, 1996). If planning and construction are to be compatible, time schedule and deadlines have to be met. This can lead to restriction in the quality of the assessment since EIA is often dependable on primary data gathering, which is time consuming. Eventually, work done by EIA consultants is subjected to evaluation by executives and policy makers who in the end make the final decision on the project development. In that process trade-offs between sectorial impacts on the environment and pre-determined environmental costs have to be balanced to satisfy both project developers and policy makers (Pugh, 1997, McCully, 1996).

9.2 The Life Cycle Analysis concept

This study uses lifecycle inventory (abridged lifecycle inventory), which is a sub methodology used under a full LCA study. *The Inventory analysis identifies and, where possible, quantifies the inputs from the environment and the outputs to the environment of the product system under analysis (European Commission,1993, p13).*

The Life Cycle Analysis (later Assessment) concept materialised as a response to increased criticisms towards the industry. It was developed to look at environmental impacts of a product through its entire life span. Combined with alarming reports from scientists and the oil crisis in the beginning of the seventies, efficiency found its place in production and development. As a result from increased awareness on environmental problems the industry was impelled to look into alternatives for improving production and decreasing pollution. One way to do so was to reduce environmental impact right at the source, thus reducing recourses and emission from production. This was seen beneficial for the industry, which could save money on production through efficiency and at the same time become environmental friendly.

The first Life Cycle Assessment was conducted when a well-known company requested a comparative analysis of beverage containers. The study was conducted by the Midwest Research Institute and focused on resource use and emission rates. This partially led to the development of the Resource and

Environmental Profile Analysis (REPA), which became a popular methodology in the early seventies and marked the real beginning of the Life Cycle Assessment methodology (Plepys, 1997, Petersen, 1997). Today LCA has developed into several procedures such as SETAC guidelines, ISO 14040.2 and the Nordic LCA guidelines, which all work towards similar goals. International standards of LCA are yet to be developed but there are some proposed methods that are recognised among researchers. The international SETAC organisation is currently working on a standardisation of LCA (Plepys, 1997).

LCA is by far the most popular methodology conducted by consultants and companies to carry out environmental assessment. It creates opportunity for companies to redesign their products to optimise efficiency and at the same time develop Eco-friendly products. Eco-design, Eco-labelling are example of concepts that have leapt forth in recent years (Ryan, 1996). Environmental improvements should in a larger context be the only driving force behind usage of LCA.

9.2.1. How does LCA work?

Several different definitions have been given on the Life Cycle concept. One given by the SETAC organisation on life cycle assessment reads as following;

> *"Life cycle assessment is a process to evaluate the environmental burdens associated with a product, process or activity by identifying and quantifying energy and materials used and wastes released to the environment; to assess the impact of those energy and material uses and releases to the environment; and to identify and evaluate opportunities to effect environmental improvements. The assessment includes the entire life cycle of the product, process or activity, encompassing extracting and processing raw materials; manufacturing, transportation and distribution; use, reuse, maintenance, recycling and final disposal. (SETAC code of practise, In, European Commission,1993, p11)*

9.2.2 Setting system boundaries

The LCA method includes total life cycle of a product or activity. It covers *extraction* process, *production* process, *usage* and *disposal*. In these four key components, *recycling, maintenance* and *transportation* are included. In the LCA process, a simplification is made of the technical system and the environmental impacts deriving from it. *System boundaries* are set to sectionalise the scope of the study. Part from needing a strict coverage on the life cycle, it does not take into account human resources but only impacts connected with physical systems (McCully, 1996). The LCA concept has become very popular in the industry and the service sector to monitor the resource and emission sources deriving from their products. In theory LCA can be described in following three points: (Plepys, 1997, p13)

- LCA is a simplified model of the technical system and the environmental impacts associated with it. Does not represent absolute understanding of the environmental impacts.
- LCA needs thoroughly coverage of the whole life cycle process but does not need a detailed study of all the parts in the cycle.
- LCA does not take into account human resources, but only impacts on humans connected with physical systems.

Processing through products life cycle can take a long time and requires substantial amount of data. Depending on the scale of the study, life cycle assessment can range from looking only at certain process of the lifecycle or carrying out a complete assessment including many sub-divided categories. Since no standardised method is yet available it has led to some confusion to what extent the actual accuracy is of the methodology. Questions such as, how should qualitative judgement balance against quantitative research and how should the data set be interpreted. These are factors that are important to consider. Related to this it is notable to mention lifecycle assessment carried out on two different baby napkin systems few years ago. Two researchers, who studied the same project unaware of each other, came to contradicting conclusions about environmental impact although having used pretty much the same data set (Weidema, 1994). Both researchers stressed that the low uncertainty level in their studies derived from their results.

The fine line of actual recognising where knowledge based assumptions start to fade into an opinion based assumption is hard to detect. Lindfors *et al.* (1995) comments on this when explaining the actual LCA procedure;

> *"The actual process of conducting an individual LCA thus involves a number of different decisions and assumptions, partly dependent on the case specific goal and partly based on generally accepted principles and more detailed rules…"(Lindfors et al. 1995,p13)*

To avoid problems that can rise from misinterpretation, data quality has become high priority in LCA studies. Lewis (1996) has recognised that LCA studies tend to be very data intensive, which has created a problem of assumption. Lewis (1996) elaborates further and explains:

> *"...because of its complexity and data intensity, it (the LCA) must be 'scientific' and 'right'. LCA has (in this context) been used many times by industry groups to 'prove' that their product is better than the alternative..."(Lewis, 1996, p1)*

What Lewis tries to explain is how cost and time factors can affect data quality. Full lifecycle assessment is practically impossible since accessibility to relevant data often is limited. When the purpose of the LCA study is defined, methodology is chosen for the research as well as quality of the data (see. figure 18). The data quality is normally specified as indicators that can be either quantitative or qualitative (Lewis, 1996).

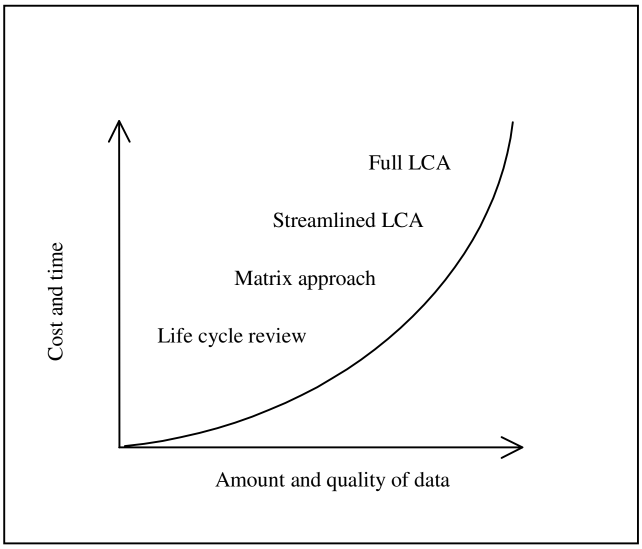

Figure 18: Data quality versus cost and time. The amount and quality of data determines what kind of approach can be used in the assessment, which is also proportionally linked to cost and time of gathering the data (Lewis, 1996).

Quantitative assessments are always combined with qualitative studies since available data is often lacking. LCA studies are thus qualitative but LCA methodology constructs a framework that provides the information of the environmental impact. Improvement in the activities or the product comes after applying the knowledge gained from the LCA (US-EPA, 1994).

When uncertainties are defined, the LCA methodology becomes very good for analysing and quantifying resources and emission from products or processes. It can identify where in the process of certain activity the most impacts are expected. Although giving the results from emission rates and resource consumption of a product. LCA does not identify directly in what way the environment is degraded. But it can serve as an excellent base for other research, which use LCA studies as part of assessing environmental degradation.

9.3 The Ecological Footprint methodology

In recent years many new studies have emerged, which try to estimate the dependence of human life on the environment. Concepts such as MIPS, LCA, Environmental Space and the Sustainable Process Index are few examples of methodologies which have one common purpose, to quantify human use of nature and point out ways to reduce the impact (Wackernagel *et al.* 1998a, Bleek, 1997).

The *Ecological Footprint* (EF) is a tool that has been developed to look at consumption and its effects on global carrying capacity. It poses a fundamental question: *how can the human beings life secure live within the means of nature?* Wackernagel & Rees (1996) define the Ecological Footprint (EF) as the following:

> *The Ecological Footprint accounts for the flows of energy and matter to and from any defined economy and converts these into the corresponding land / water that are required from nature to support these flows. (Wackernagel & Rees, 1996, p3)*

According to Wackernagel & Rees (1996), the Ecological Footprint is an accounting tool which makes it possible for us to estimate the resource consumption and waste assimilation demands of a particular human population and economy. The human economy can be thought as having "industrial metabolism" similarly to a cow on a pasture field which needs to feed on resources and get rid of waste. The larger the metabolism, the larger biological land area is needed to sustain it. Since people use resources from all over the globe and affect distant places with their waste, the footprint methodology sums up all these ecological areas, regardless where they are posited (Wackernagel, 1998b).

9.3.1 How is the footprint calculated?

If the total biological land area and sea space on the planet is divided with the total world population the results will be an average 2.2 ha per person. This number represents the total available biologically productive land area and sea space for every person at this given moment. This is known as *fair Earthshare*. From the total number 2.2 ha, 1.7 is allocated on land in the form of forests, pasture and arable lands, 0,5 ha is ecological productive sea areas, which are mostly located on continental shelves. As population increases every year the fair Earthshare per person decreases since more people have to share the limited land area. Similarly, if the total productive land area is decreasing due to erosion and degradation the fair Earthshare decreases (Wackernagel, 1998b). At the turn of the last century the fair Earthshare was 5.6 ha per person but with current estimate of global population reaching 10 billions in the year 2050, the fair Earthshare is expected to slide down to 1.2 ha per person (Wackernagel & Rees, 1996, Wackernagel, 1998b)

Ecological productivity varies from places to places around the globe. Wackernagel & Rees (1996) has calculated the footprint of 52 nations, which covers 80% of the world population. He used the United Nation statistical data set from 1993 to calculate and rank the footprint of these nations. For example the average Canadian needs 6,7 ha of ecological productive land and 1 ha sea-space, or a total of 7,7 ha to sustain his lifestyle. The ecological capacity of Canada is 9.6 hectare per person since it has large forest areas and pasture. If we subtract this number from the footprint per capita we actually end up with 1.9 ha surplus. Similarly, the Swedish footprint is about 6 ha per person but the country has ecological capacity of 7.0 ha per capita. This could seem as Sweden and Canada are sustainable since their footprint per person is below the region carrying capacity, but that is not the case. Hong Kong for example has almost no ecological capacity. Still the inhabitants use 6.1 ha per person to sustain their lifestyle. This footprint, which is in the form of products and necessities, is imported from other regions. It leaves Hong Kong with ecological deficit of 6.1 ha. Many other countries, which are in similar position as Hong Kong rely on ecological surplus from other regions (Wackernagel, 1998b). If the total ecological capacity of the world is compared to the total ecological deficit of all countries, the results will be a deficit of 0.7 hectare per person (Wackernagel, 1998b). This reveals that the world population is exceeding carrying capacity by 35%. This is known as overshoot and is possible since the effects of depleting the natural capital is not felt instantly but is delayed. This can be related to bank account that has certain amount of money. As soon as one starts to withdraw more from the bank account than the interest rate can cover the total amount decreases, but it is possible to withdraw for a period of time before the account is empty (Wackernagel & Rees 1996, Meadow *et al.* 1992).

When assessing environmental impact with the ecological footprint methodology, six following ecological categories are used to calculate the footprint. *Fossil energy land, arable land, pasture, forests, build up areas and sea-space.* Following table 11 explains in details how these categories are allocated in the footprint.

Table 11: Six major categories of productive space used in the ecological footprint (adopted from Wackernagel, 1998a, http://www.ecoucil.ac.cr/rio/focus/report/english/footprint/biological.htm)

Fossil energy land is the land that we should reserve for CO_2 absorption. But today we don't - insignificantly little area is set aside to absorb CO_2. In other words, neither the biochemical energy of the used fossil fuel is replaced nor its waste products absorbed. In this respect, humanity is living off nature's capital rather than its interests. Also using fossil fuel based products or burning fossil fuels can release toxic pollutants, an additional ecological hazard not yet included in these footprint calculations (for example, plastics can contain heavy metals such as cadmium etc.).

Arable land is ecologically speaking the most productive land: it can grow the largest amount of plant biomass. According to the Food and Agriculture Organization of the United Nations (FAO), nearly all of the best arable land, or about 1.35 billion hectares, is already under cultivation. 10 million hectares of it are abandoned annually because of serious degradation. This means that today, there exist less than 0.25 hectares per capita world-wide of such highly productive land.

Pasture is grazing land for dairy and cattle farming. Most of the 3.35 billion hectares of pasture, or 0.6 hectares per person, are significantly less productive than arable land. For example, its potential for accumulating biomass is much lower than that of arable land. In addition, conversion efficiencies from plant to animal reduce the available biochemical energy to humans by typically a factor of ten. Expansion of pastures has been a main cause of shrinking forest areas.

Forest refers to farmed or natural forests that can yield timber products. Of course, they secure many other functions too, such as erosion prevention, climate stability, maintenance of hydrological cycles, and if they are managed properly, biodiversity protection. With 3.44 billion hectares covering our planet, there are 0.6 hectares per capita world-wide. Today, most of the forests left occupy ecologically less productive land with exception of some few remaining inaccessible jungle areas.

Built-up areas host human settlements and roads and extend approximately 0.03 hectares per capita world-wide. As most human settlements are located in the most fertile areas of the world, *built-up land* often leads to the irrevocable loss of prime arable land.

Sea space *The sea* covers 36.6 billion hectares of the planet, or a little over 6 hectares per person. Roughly 0.5 hectares out of these 6 hectares harbour over 95 percent of the seas' ecological production. This marine production is already harvested to the maximum. Because the fish that people fancy are high up in the food chain, the food gains from sea space remain limited. These 0.5 hectares provide approximately 18 kilogram of fish per year of which only 12 kilogram end up on people's dinner tables, securing thereby only one and a half percent of humanity's caloric intake. Measuring the ecological activity of the sea by its area (and not its volume as many intuitively think) makes sense. It is surface which determines its productivity, as both the capturing of solar energy and the gas exchanges with the atmosphere are proportional to the surface.

In the ecological footprint assessment, the global average in biological productivity has a yield factor 1. Since regions around the world differ in ecological productivity, the yield factor varies. For instance if a country is located in desertificated areas, it can have a region with a yield factor 0,5 that indicates 50% less productivity than the global average (Wackernagel, 1998a). Similarly if regions are located in a boosted agricultural area it can have a yield factor 1.5 or 50% above the global average.

9.3.2 calculations

Wackernagel & Rees (1996) further explain how the above categories are linked with consumption;

> *"...For every item of material or energy consumption, a certain amount of land in one or more ecosystem categories is required to provide the consumption-related resource flows and waste sinks...To determine the total land area required to support a particular pattern of consumption, the land-use implications of each significant consumption category must be estimated. Since it is not feasible to assess land requirements for the provision, maintenance and disposal of each of the tens of thousands of consumer goods, the calculations are confined to select major categories and individual items....While the description refers to resource consumption, the same logic would apply to many categories of waste production and assimilation."(Wackernagel & Rees, 1996, p63-64)*

The ecological footprint calculates consumption per capita. If we calculate the number of certain item such as energy, food, forest products production or consumption, per person in a given population (corrected for trade = production + import-export) we can calculate its Footprint (Wackernagel & Rees, 1996). Following table shows the calculation procedure (table 12).

Table 12: The calculation procedure for the ecological footprint (Wackernagel & Rees, 1996)

$aa_i = c_i / P_i$ $ef = \quad aa_i$ $\mathbf{EF_p = N\,(ef)}$
aa: land area appropriated per capita i: production of consumption item c: average annual consumption of an item P: average annual productivity or yield of an item ef: total ecological footprint of the average person EF_P: The ecological footprint of the study population.

Consumption has been separated into six major categories, which serve as a basis for classification of statistical data. These are: *Food, housing, transport, consumer goods, services and waste*. All these categories can be divided into sub-categories to answer more specified questions (Wackernagel & Rees, 1996). The ecological footprint calculations are based on eight major land categories (table 13). Every category has its embodied ecological footprint, either through embodied energy and resources which are the total amount of energy and material used through a lifecycle of a commodity, or through energy intensity which is the embodied energy per unit of service or goods (Wackernagel & Rees, 1996).

Table 13: The main land and consumption categories. This example shows summaries of more detailed EF calculations in m^2.

CATEGORIES	A) FOSSIL ENERGY LD.	B) ARABLE LAND	C) PASTURE	D) FOREST	E) BUILT-UP LAND	F) SEA	TOTAL
1.- FOOD	*1 041*	*3 401*	*4 791*	*0*	*0*	*147*	9 381
2.-HOUSING	*484*	*662*	*0*	*1 089*	*1*	*0*	2 237
3.-TRANSPORTATION	*2 677*	*0*	*0*	*0*	*3*	*0*	2 680
4.-GOODS	*93*	*0*	*463*	*105*	*0*	*0*	661
5.-SERVICES	*295*	*0*	*0*	*0*	*0*	*0*	295
6.-WASTE	*80*	*0*	*0*	*94*	*0*	*0*	174
TOTAL	4 669	4 064	5 254	1 289	5	147	15 428

The ecological footprint can be used to analyse large systems such as national economy, and smaller units such as households.

9.3.3. Energy to land

Perhaps the most challenging task in estimating the footprint is the energy to land. Since energy is produced through different sources the footprint will vary considerably. For instance will coal fired powerplant have different footprint than wind-powered energy. The ecological footprint evaluates the productivity of different sources in ha per year and the higher the productivity the smaller the footprint will be. Fossil fuels for instance have productivity around 80-100 Gj per hectare per year, as hydro powerplant has productivity around 1000 Gj per hectare per year. Wind power has productivity between 12,500- 25,000 Gj per hectare per year, but nuclear energy has productivity up to 50,000 Gj per hectare per year given that environmental externalities are not accounted for (Wackernagel & Rees, 1996).

There exist several methods to convert fossil fuels to corresponding land area. Although three approaches are used, they produce approximately the same results (Wackernagel & Rees, 1996, p72-73):

1. Calculation of the land required to produce a contemporary biologically- produced substitute for liquid fossil fuel, in this case ethanol or methanol. Ethanol productivity is max ~80 GJ per hectare per year of ecological productive land. For Methanol, average forest productivity would yield 30-70 GJ per hectare per year.
2. Estimation of the land area needed today to sequester the CO_2 (carbon sink) emitted from fossil fuels. Average forests can accumulate around 1.8 ton carbon per hectare per year. In other words, one hectare of average forest can sequester annually the CO_2 emitted from burning 100 GJ of fossil fuel.
3. Estimation of the land area required to rebuild natural capital at the same rate as fossil fuel is being consumed. If we assume that depleted natural capital must be replaced, the land-for-energy ratio amounts to 80 GJ of biomass energy per hectare per year.

These three approaches of converting fossil fuel to its corresponding land area give the results, 80-100 Gj of fossil fuel per year, for one hectare used land. When the energy to land ratio has been defined it becomes possible to analyse most systems through the ecological footprint concept. If all environmental factors regarding nuclear power are put together such as risk for contamination, emissions (1/6 of coal fired plant if the total uranium cycle is included), storing waste, and closing down the reactors are assessed, nuclear power can be positioned on equal basis with coal fired plant. Thus nuclear power has productivity equalling 100 GJ per hectare per year. This study uses the above arguments when assessing the environmental impact of the building materials (Wackernagel & Rees, 1996, Miller, 1996).

What are the most critical aspects to the footprint methodology? The authors themselves state that the ecological footprint underestimates the land requirements of an economy. Partly because it does not consider more biophysical life-support service, especially those that are not directly associated with land-based renewable resources production (Wackernagel & Rees, 1996). But Wackernagel & Rees (1996) elaborate further by stating;

> *"First there is virtue in accurate simplicity. However complete theory or model purports to be, it cannot include all aspects of reality. (A) good theory finds a balance between complexity and simplicity- to be effective in guiding policy, models must be good enough to capture the essence of reality but simple enough to be understood and applied.... A second reason for keeping things simple is that certain ecosystem functions are analytically intractable..." (Wackernagel & Rees, 1996, p62-63)*

Although the ecological footprint methodology is still in its infancy and still developing it evaluates the human impact on the environment in a quantitative way. It simplifies the concept of sustainability and brings the discussions from the table to action.

9.4 Systemic approach and Causal loop diagrams

This chapter will explain the theory and the concept of causal loop diagrams used in this thesis. This concept can be helpful in explaining the interactions between elements in the society and how it connects to ecological living.

A system can be defined as a collection of components that interact and function together for some purpose. The system can be a society and an ecosystem. A system is never a single disciplinary problem but requires multi dimensional approach. Since systemic approach cuts through different academic fields, drawing boundaries for the study requires rational thinking. To define system boundaries in a study is always challenging, it requires a good knowledge of the problem at hand (Roberts *et al.* 1983).

9.4.1 Explaining the causal-loop concept

System thinking can be described as process thinking, understanding cause and effect between different components within a defined system. Systems always behave in a circular organisation forming a so-called feedback loops. Capra (1996) describes feedback loops as:

> *"...circular arrangement of causally connected elements, in which an initial cause propagates around the links of the loop, so that each element has an effect on the next, until the last, "feedback" the effect into the first element of the cycle..." (Capra, 1996, p56)*

The effects of the last element influence the input of the first element, which results in a self-regulation of the whole system. Regulation of a system can either result as self-reinforcing or self-balancing. Reinforcing is an escalating effect due to equivalent influences between the components, which can be either downward spiral or upward. To put system thinking in practise, several rules have to be followed so that "cause" and "effect" can be monitored in a right way (see table 14).

Table 14: Summarised explanation of the causal loop concept (adopted from Roberts *et al.* 1983, p56)

Symbol	Meaning
Arrow Tail ——→ Head	The arrow is used to show causation. The item at the tail of the arrow cause a change it the item at the head of the arrow.
——→ +	The + sign near the arrowhead indicates that the item at the tail of the arrow and the item at the head of the arrow change in the *same* direction. If the tail *increases*, the head *increases*; if the tail *decreases*, the head *decreases*.
——→ —	The – sign near the arrowhead indicates that the item at the tail of the arrow change in the *opposite* direction. If the tail increases, the head decreases; if the tail decreases, the head increases.
(—) or (—)	This symbol (also B), found in the middle of a closed loop, indicates that the loop continues going in the same direction, often causing either systematic *growth* or *decline*, behaviour that unstable moves away from equilibrium point. This is called a *positive feedback loop*.
(+) or (+)	This symbol (also R), found in the middle of a closed loop, indicates that the loop changes direction, causing the system to *fluctuate* or to *move toward equilibrium*. This is called *a negative feedback loop*.

Following example (figure 19) is as system that is escalating. In this case net population increases from increases in births. This system is typical for populations that have higher birth rate than death rate. By going through it step by step following reasoning can be made: *Increased population increases birth, in which population increases*. This is a reinforcing system indicated with little "R" loop in the middle (plus sign can also be used). The graph on the right indicates exponential growth (See figure 19):

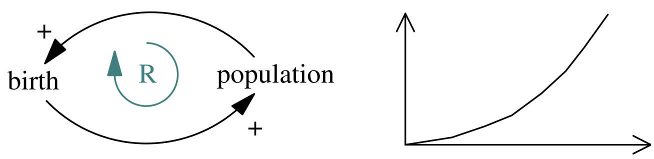

Figure 19: An example of an escalating system.

If birth would be replaced by death, the system would also be reinforcing but escalating exponential downwards. In actual situation death rate would balance increase in population since population is not immortal, the factor "death" can be added to the system to balance it (figure 20).

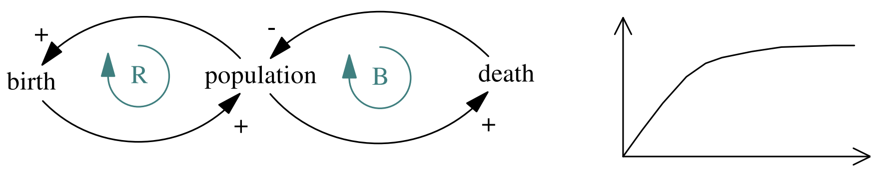

Figure 20: An example of balancing system

The system is now balanced toward some initial point that is determined by the number of births or the number of deaths. Despite complexity, all systems attempt to balance themselves in one way or another. The central importance for analyst is to identify key components and study their interactions. Roberts, *et al.* (1983) give good interpretation on the system thinking works in practise:

> "*...Causal thinking is the key to organising ideas in a system dynamics study. Typically an analyst isolates key causal factors and diagrams the system of causal relationships, before proceeding to build a computer simulation model. However, the notion of causation can be subtle, and using the concept requires careful attention*." (Roberts, *et al.* 1983, p11)

In following causal loop explanation the above arguments will be fulfilled as well as possible. Creating a causal relationship requires an unbiased mind but rational thinking and that is the base of the analysis.

9.4.2 Conceptual loop diagram of industrial- and ecological lifestyle

Western lifestyle is dependant on resources extracted from all over the world. The Swedish lifestyle can be considered as a typical industrial lifestyle. Following loop diagrams is a conceptual model of typical western lifestyle. Ecological lifestyle can be defined as a lifestyle which fundamentally uses the same resource base, but more efficiently or less. It can also be regarded as an alternative lifestyle in which individuals utilise local resources and energy.

Three main indicators can be used to describe basic living in a simple way. These factors are *resources, living* and *waste*. In our daily life, resource extraction and waste disposal are fundamental activities for our existence, regardless to where in the world we are or in which part of the globe one is situated.

The United Nation have defined the four basic needs for living which need to be fulfilled for a qualitative lifestyle, these are: food, shelter, water and clothing (Miller, 1996). What makes fundamental difference in terms of living is how one lives or dwells. The difference between cultures is enormous. The industrialised countries, which count for 25% of the world population, consume roughly 75% of the total extracted resources. The industrialised world has developed certain living standard that is dependant on mass consumption and accumulation of wealth. Since the economy of the free marked is dependant on continuous growth, a consumption lifestyle is very much promoted. Economic growth is directly connected with consumption and generally, societies consider themselves rich if certain social standards are fulfilled (Miller, 1996). These standards can be education, elderly care, hospitalisation, leisure activities, transport system etc, all are activities that are designed to make life more comfortable. More or less all countries strive towards this goal but since modern industrialisation is a high energy demanding activity many countries can not afford it, especially in Africa and Asia. Increased industrialisation requires increased resource flow to uphold the material standard.

The world natural capital cannot sustain current consumption. Living well on less is needed to cope with increased population growth and degradation of the world ecosystems. Ecological lifestyle is a lifestyle, which does not compromise quality of living but instead promotes a resource and energy reduced lifestyle.

9.4.3 Industrial lifestyle

Following diagrams will try to explain typical industrialised living standard and what factors are associated with it. Sweden can be categorised as a typical industrial country with common industrial living standard known in the Northern Hemisphere. Although Sweden has a large natural capital base (~7 hectare per capita), the country still gathers resources in the form of services and imports of goods. Well accessible resources that are inexpensive increase conventional *industrial living standard* (or lifestyle) which in turn indirectly decreases the natural capital (the common resource pool).

Three main factors can be identified as general driving forces in the society. *Lifestyle (industrial)* promotes mass *consumption,* which increases economic *growth*. Between these three factors we have a reinforcing situation which sustains itself as long as resources are abundant. Mass consumption is basically resource extraction that flows through the economy (see figure 21).

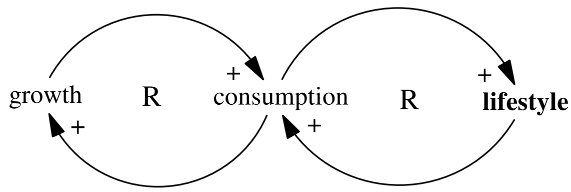

Figure 21: Industrial lifestyle is indirectly dependant on the flow of resources.

Since the whole system is dependent on the natural capital this situation can not be supported for a long time. The balancing factor for the system is the limited natural capital (see figure 22). But the consumer economy can still grow if new technologies are invented to access more remote resources (e.g. offshore oil drilling). New resources make up for depleted local ones and still maintain the consumption. This can sustain the whole economy for a longer time but at the risk of going into an overshoot of the *natural capital*. (See figure 22).

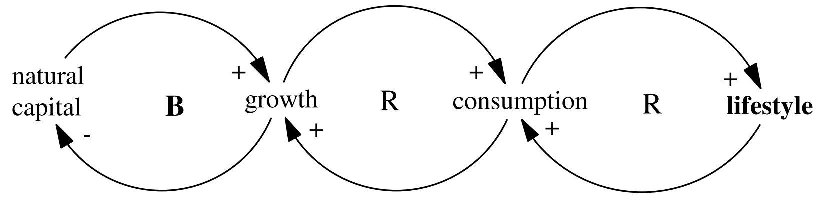

Figure 22: The natural resources act as a buffer on the expansion of the economical system.

9.4.4 Ecological lifestyle

New technologies that are designed to access resources more easily affect whole ecosystems. Increased environmental awareness and fundamental changes in the economy can promote eco-lifestyle. *Eco-lifestyle* reduces *consumption*, which leads to reduced (economic) *growth* and eventually increase in the *natural capital* (see figure 23).

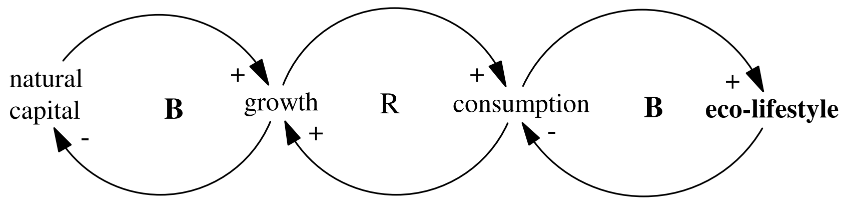

Figure 23: Ecological lifestyle reduces consumption and degradation of the natural capital.

The figure 23 can be described as a system that is moving from an expanded economy to a steady state economy. According to the economist Herman Daly, (1993) steady state economy is the only sustainable option that can propel us into the next century. If we comply with Daly's arguments then the following can be observed: *Ecological lifestyle* has to promote *steady state economy* in order to reduce the *rate of consumption*. *Steady state economy* reduces *resource flow* but increases *recycling* which in turn reinforces the *steady state economy*. Here we have two loop-diagrams that are reinforcing each other, which will result in recovery of the natural capital (see figure 24).

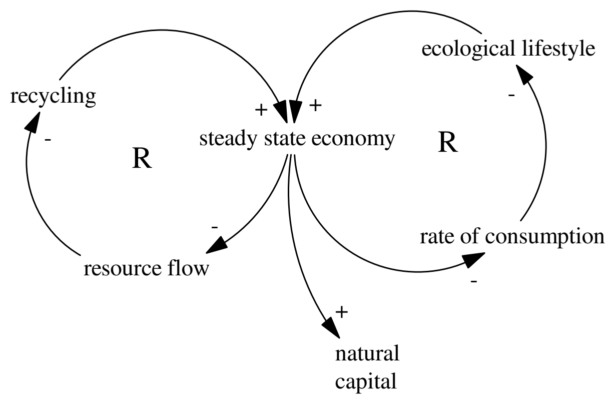

Figure 24: Ecological lifestyle is connected to steady state economy.

The whole system is constrained by the number of people. The natural capital can only sustains a certain number of people. The higher the population gets the higher the degree of ecological lifestyle is needed. This can be related to the ecological footprint and the concept of *fair Earthshare.* Decreasing *fair Earthshare* (or decreasing the natural capital) means greater challenge and more demands on eco-lifestyle (See figure 25).

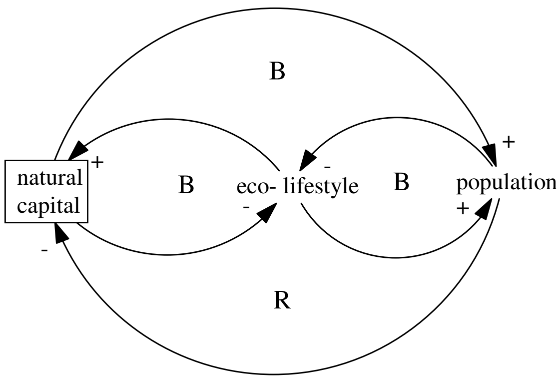

Figure 25: The number of people on the planet determines the carrying capacity or the *fair Earthshare*. Even if ecological lifestyle is promoted it is restricted by the number of people.

The political challenge for the next century is great and calls for fundamental change in perception. The perception today is that political willingness is pretty much steering how sustainable development is promoted. Since GNP is perceived as an indicator of welfare in the world, nobody is willing to compromise economic growth for increased ecological living. In fact the Brundland Report on sustainable development states that one of the important factors for sustainable development is economic growth (Andersson, *et al.* 1995). For poor countries to have the strength to tackle environmental problems they have to have the economical capacity. The following figure 26 is a good example how today's perception is contradicting sustainable development. Some environmental economists agree on, in order to achieve sustainable development, economic growth has to slow down and societal welfare indicators have to change. Powerful industrial lobbyists are constantly putting pressure on the politicians, which in turn are reluctant to change policy (see figure 26).

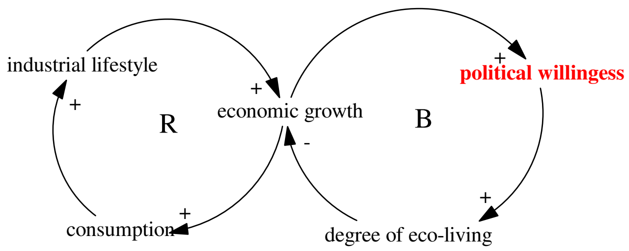

Figure 26: Politicians are steered by economical goals.

On the other hand grassroots organisation can be powerful in demonstrating their power of consumer behaviour. Green labelling is a good example of increased consumer awareness and an indicator how the industry is shifting towards more eco-friendly products (Karamanos, 1995). As the public becomes more informed about the relationship between consumption and environmental degradation, the industry is pushed into a new form of competition in making things more resource efficient and recycled. But it does not mean that consumption is necessarily decreased. Despite increased corporate and consumer awareness on the environment, economic growth is still increasing and trade agreements (such as GATT and Nafta) are being formed to allow access to new markets and to find new consumers (see figure 27).

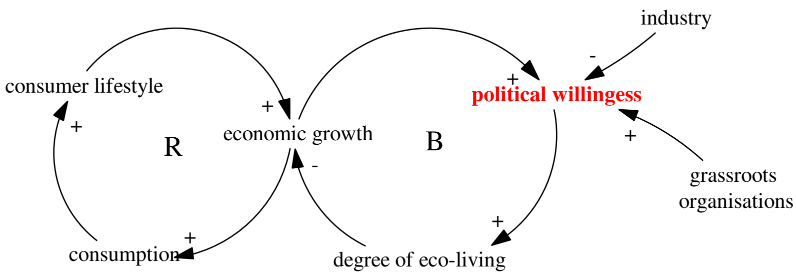

Figure 27: Conflict exists between the industry and the grassroots organisations.

Even though the industry and environmental organisations have shared vision on sustainability, conflicts between short-term commercial goals and long term political goals exists. Not many corporations are willing to compromise their expansion and possible profits for long term goals of sustainable development. This is why there generally exists tug of war between the industry and "green" organisations on how politicians should form the future policies.

As demonstrated in above examples, the causal loop concept is a good tool for identifying driving forces and can be considered as vital part of any research.

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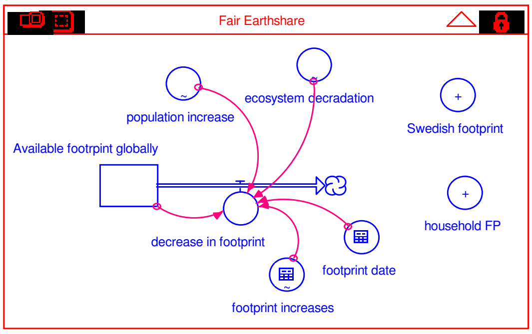
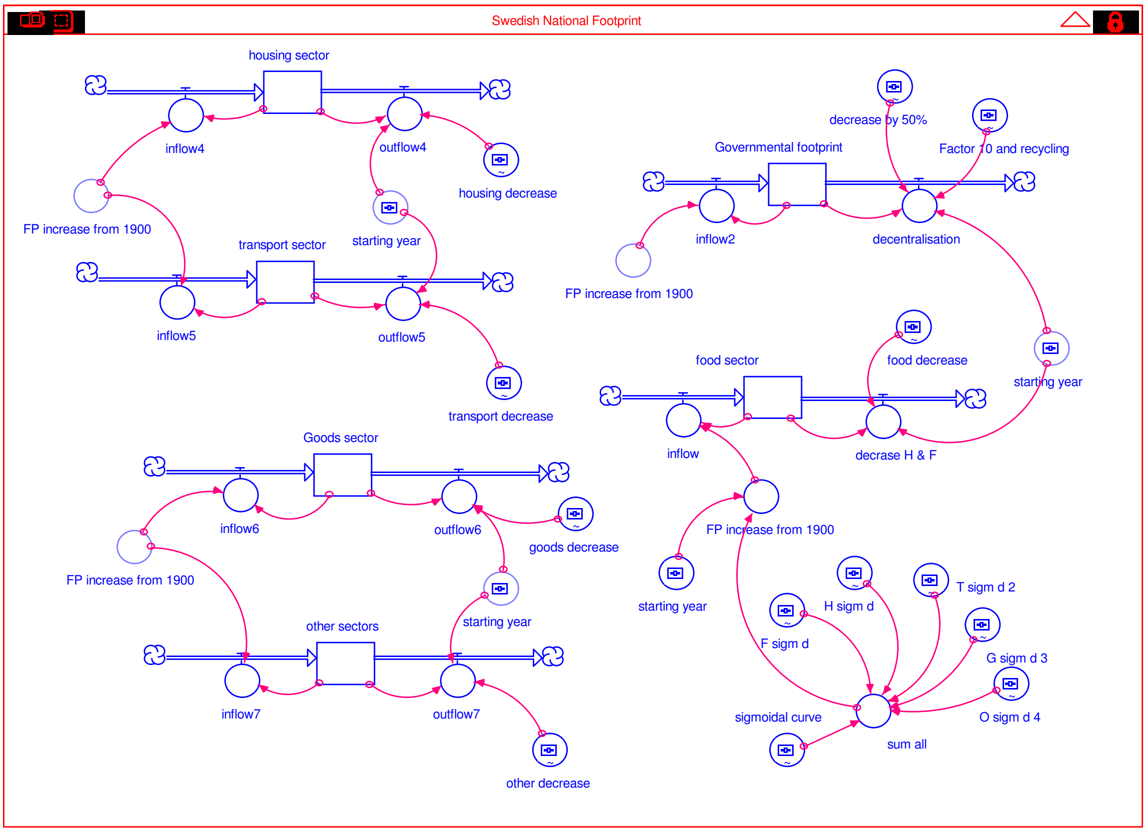
Appendix II: Model preferences





Appendix III: Model formulas

```
Available_footrpint_globally(t) = Available_footrpint_globally(t - dt) + (- decrease_in_footprint) * dt
INIT Available_footrpint_globally = 5.6
OUTFLOWS:
decrease_in_footprint = if time >= footprint_date then (footprint_increases*Available_footrpint_globally) else (Available_footrpint_globally*ecosystem_decradation) +
(population_increase*Available_footrpint_globally)
food_sector(t) = food_sector(t - dt) + (inflow - decrase_H_&_F) * dt
INIT food_sector = 0.191 {1.14 {57% of the total swedish footprint 0.382409}
INFLOWS:
inflow = food_sector*FP_increase_from_1900
OUTFLOWS:
decrase_H_&_F = if time>=starting_year then (food_sector*food_decrease) else 0
Goods_sector(t) = Goods_sector(t - dt) + (inflow6 - outflow6) * dt
INIT Goods_sector = 0.03817 {0.076359}
INFLOWS:
inflow6 = Goods_sector*FP_increase_from_1900
OUTFLOWS:
outflow6 = if time>=starting_year then (Goods_sector*goods_decrease) else 0
Governmental_footprint(t) = Governmental_footprint(t - dt) + (inflow2 - decentralisation) * dt
INIT Governmental_footprint = 0.43 {0.86}
INFLOWS:
inflow2 = Governmental_footprint*FP_increase_from_1900
OUTFLOWS:
decentralisation = if time>= starting_year then (Governmental_footprint*Factor_10_and_recycling)+(decrease_by_50%*Governmental_footprint) else 0
housing_sector(t) = housing_sector(t - dt) + (inflow4 - outflow4) * dt
INIT housing_sector = 0.241 {0.482862}
INFLOWS:
inflow4 = housing_sector*FP_increase_from_1900
OUTFLOWS:
outflow4 = if time>=starting_year then (housing_sector*housing_decrease) else 0
other_sectors(t) = other_sectors(t - dt) + (inflow7 - outflow7) * dt
INIT other_sectors = 0.02287 {0.045741}
INFLOWS:
inflow7 = other_sectors*FP_increase_from_1900
OUTFLOWS:
outflow7 = if time>=starting_year then (other_sectors*other_decrease) else 0
transport_sector(t) = transport_sector(t - dt) + (inflow5 - outflow5) * dt
INIT transport_sector = 0.0763 {0.152671}
INFLOWS:
inflow5 = transport_sector*FP_increase_from_1900
OUTFLOWS:
outflow5 = if time>=starting_year then (transport_sector*transport_decrease) else 0
footprint_date = 2050
FP_increase_from_1900 = if time >= starting_year then sum_all else 0.0183 {0.0183 initial}
household_FP = food_sector + Goods_sector + housing_sector + transport_sector + other_sectors
starting_year = 2000
sum_all = sigmoidal_curve-(F_sigm_d+H_sigm_d+T_sigm_d_2+G_sigm_d_3+O_sigm_d_4)
Swedish_footprint = food_sector + Goods_sector + Governmental_footprint + housing_sector + other_sectors + transport_sector
decrease_by_50% = GRAPH(time)
(2000, 0.00), (2005, 0.0105), (2010, 0.0165), (2015, 0.022), (2020, 0.023), (2025, 0.023), (2030, 0.021), (2035, 0.016), (2040, 0.0105), (2045, 0.00), (2050, 0.00)
ecosystem_decradation = GRAPH(time {0.01decrease per month 0.000833})
(1900, 5e-005), (1913, 0.0002), (1925, 0.0004), (1938, 0.0007), (1950, 0.001), (1963, 0.0014), (1975, 0.002), (1988, 0.00275), (2000, 0.00335), (2013, 0.0037), (2025, 0.00405), (2038,
0.00415), (2050, 0.00415)
Factor_10_and_recycling = GRAPH(time)
(2000, 0.00), (2005, 0.021), (2010, 0.0405), (2015, 0.0595), (2020, 0.075), (2025, 0.09), (2030, 0.09), (2035, 0.0615), (2040, 0.032), (2045, 0.00), (2050, 0.00)
food_decrease = GRAPH(time)
(2000, 0.0715), (2001, 0.0715), (2002, 0.0715), (2003, 0.0715), (2004, 0.0715), (2005, 0.0715), (2007, 0.0715), (2008, 0.0715), (2009, 0.0715), (2010, 0.0715), (2011, 0.00)
footprint_increases = GRAPH(time)
(2000, 0.014), (2005, 0.0136), (2010, 0.0132), (2015, 0.0121), (2020, 0.0109), (2025, 0.00922), (2030, 0.00742), (2035, 0.00558), (2040, 0.00396), (2045, 0.00202), (2050, 0.00)
F_sigm_d = GRAPH(time)
(2000, 0.00176), (2008, 0.00173), (2016, 0.00168), (2024, 0.00147), (2032, 0.00112), (2040, 0.000756), (2048, 0.000522), (2056, 0.000324), (2064, 0.000162), (2072, 0.00), (2080, 0.00)
goods_decrease = GRAPH(time)
(2000, 0.056), (2002, 0.057), (2003, 0.057), (2005, 0.058), (2006, 0.059), (2008, 0.06), (2009, 0.06), (2011, 0.06), (2012, 0.057), (2014, 0.06), (2015, 0.00025)
G_sigm_d_3 = GRAPH(time)
(2000, 0.00075), (2008, 0.00074), (2016, 0.000675), (2024, 0.000595), (2032, 0.000485), (2040, 0.000395), (2048, 0.000255), (2056, 0.00013), (2064, 3.5e-005), (2072, 0.00), (2080, 0.00)
housing_decrease = GRAPH(time)
(2000, 0.15), (2002, 0.15), (2003, 0.15), (2005, 0.149), (2006, 0.149), (2008, 0.149), (2010, 0.148), (2011, 0.148), (2013, 0.148), (2014, 0.147), (2016, 0.001)
H_sigm_d = GRAPH(time)
(2000, 0.00398), (2008, 0.004), (2016, 0.004), (2024, 0.00362), (2032, 0.00296), (2040, 0.00242), (2048, 0.00182), (2056, 0.00126), (2064, 0.00078), (2072, 0.00026), (2080, 0.00)
other_decrease = GRAPH(time)
(2000, 0.051), (2002, 0.0525), (2003, 0.0505), (2005, 0.0515), (2006, 0.0525), (2008, 0.0525), (2009, 0.0525), (2011, 0.0525), (2012, 0.0525), (2014, 0.0525), (2015, 0.00)
O_sigm_d_4 = GRAPH(time)
(2000, 0.000305), (2008, 0.000295), (2016, 0.00029), (2024, 0.00027), (2032, 0.00023), (2040, 0.00019), (2048, 0.00013), (2056, 7.5e-005), (2064, 3e-005), (2072, 0.00), (2080, 0.00)
population_increase = GRAPH(time {0.009decrease per month 0.00075})
(1900, 0.0005), (1915, 0.0041), (1930, 0.0073), (1945, 0.0093), (1960, 0.0106), (1975, 0.011), (1990, 0.0111), (2005, 0.0108), (2020, 0.0099), (2035, 0.007), (2050, 0.00)
sigmoidal_curve = GRAPH(time)
(2000, 0.018), (2008, 0.0176), (2016, 0.0157), (2024, 0.0112), (2032, 0.00801), (2040, 0.00477), (2048, 0.00297), (2056, 0.0018), (2064, 0.00072), (2072, 0.00018), (2080, 0.00)
transport_decrease = GRAPH(time)
(2000, 0.105), (2002, 0.103), (2003, 0.103), (2005, 0.106), (2006, 0.106), (2008, 0.104), (2010, 0.105), (2011, 0.105), (2013, 0.105), (2014, 0.105), (2016, 0.00)
T_sigm_d_2 = GRAPH(time)
(2000, 0.001), (2008, 0.001), (2016, 0.001), (2024, 0.000995), (2032, 0.000675), (2040, 0.00047), (2048, 0.000325), (2056, 0.00019), (2064, 7.5e-005), (2072, 0.00), (2080, 0.00)
```

Appendix IV: The ecological footprint evaluation form (Swedish translation)

Kategorier	**Konsumtion per månad**
1. Mat	
Grönsaker, potatis & frukter (markera % egen odlad)[kg]	
Bröd [kg]	
Ris, gryn, pasta, spagetti etc. [kg]	
Bönor & ärtor [kg]	
Mjölk & yoghurt [kg]	
Ost & smör [kg]	
Ägg [antal, 50g styck]	
Kött,	
…gris [kg]	
… kyckling, kalkon [kg]	
… nötkött [kg]	
… nötkött (ekologiskt) Lamm [kg]	
Fisk [kg]	
Juice & Vin [kg]	
Socker [kg]	
Matolja & matfett	
… margarin [kg]	
… matolja [l]	
Te & Kaffe [kg]	
Restaurang & snabbmat [antal hela måltider]	
Personlig trägårds odling [m^2]	
2. Boende	
Boende yta [m^2]	
… hur stor del av huset är tegel ca. %	
… hur stor del av huset är trä ca. %	
Trägård *(areal som inte är för odling)* [m^2]	
Elektricitet *(El- konsumtion per månad)* [kWh]	
Olja (1m3 = 1000 l) [l]	
Gas [kg] eller [m^3]	
Halm- / Flis eldning [kg]	
Ved, trä (för eldning) [kg] eller [m^3]	
Vattenåtgång [m^3]	
Virke, trä i möbler etc [kg]	
(uppskatta hur mycket trä finns i era möbler)	
3. Transporter	
Bussar/ tåg [personer* antal km]	
Taxi / eller andra bilar [km]	
Bensin (om du har egen bil) [l]	
Reparations delar [kg]	
Flygplan [personer* timmar]	
4. Gods / Varor	**Konsumtion per månad**

Kläder (om ni köpt begagnat, räkna 1/3 del av vikten)	
… bomull [kg] (ett par byxor väger ca 0,5 kg)	
… ull [kg]	
… syntetiska [kg]	
Pappers produkter (tidningar etc.) [kg]	
Verktyg, metall delar etc. [kg]	
Läder, skinn [kg]	
Plast produkter och foton [kg]	
Porslin, glas [kg]	
Medicin [kg]	
Hygien produkter, tvål, diskmedel etc. [kg]	
Cigaretter [kg]	
5. Tjänster (ungefärligt)	
Kemtvätt [kg]	
Post	
… internationell [kg]	
… lokalt [kg]	
Försäkringar [kr]	
Telefon [kr]	
Läkar / Vårdtjänster [kr]	
Underhållning [kr]	
Utbildning (CSN-lån) [kr]	
6. avfall (förpackningar, kompost)	
Hushåll avfall	
… papper [kg]	
… aluminium (burkar) [kg]	
… magnetisk metall (radio, tv etc) [kg]	
… glas [kg]	
… plast [kg]	

Ytterligare frågor:
Vilken är din utbildning? (kryssa för båda vuxna)

Grundskola	Gymnasieskola	Högskola	Universitet
☐	☐	☐	☐

Viktigt!
Antal boende i huset?
vuxna:_______
barn:________

Vilket yrke passar Er best? (kryssa för båda vuxna. Om ni är pensionerade, kryss det och tidigare yrke.)

Revision/Ekonomi	*Dator relaterad*
Konsult	*Ingenjör*
Statlig sektor	*Jurist*
Industri/verkstad	*Vårdsektor*
Forskning/utveckling	*Reklam/Försäljning*
Arbetslös	*Pensionär*

Annat:______________________________