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Is Ecological living sustainable? – a case study from two Swedish villages in South Sweden

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ABSTRACT

Sustainable issues need to be investigated on both spatial and temporal scales. Scale level interactions in different societal sectors suggest that the sustainability concept is ranging depending on the observed time scale. A western household system has an expected duration of 50 years. The sustainability time perspective is thus limited to this period, as since households do not plan generations ahead. Lifestyle patterns, including "ecological living" is influenced by several factors, mainly living and consumption. Dynamic simulation can identify important components of a lifestyle that maintain the highest Ecological Footprint value through time. Ecological footprints are calculated by converting the living and consumption to corresponding ecosystems areas required to support the production of the needed material. System analysis was used to simulate development of the ecological footprint over time of two lifestyles from two different townships in southern Sweden; an ecological village; Toarp; and a conventional village; Oxie, both situated in the same region in South Sweden. The Simulation spans over a 50-year period and included sensitivity analysis of several scenarios of living and consumption pattern. The construction of ecological houses is only giving minor reduction in the environmental impact. The result indicate that the "food" consumption and space heating, which contribute around 70% of the total ecological footprint, are the most realistic alternative in order to reduce the environmental impact of households.

Objectives

The objectives of the study were to analyse and identify the differences between ecological living and conventional living in south Sweden. Furthermore to identify the most important driving forces in household consumption in a fifty year perspective and possible alternatives to reduce its impact.

1.0 Introduction

Much has been debated on how to reach sustainability within cities and what the concept sustainability implies. For many people sustainability has to do with sustaining human activities, such as economic growth, jobs or political stability. Others consider sustainability of cities a combination of meeting people's needs and the commitment to sustaining the natural capital. According to Rees (1997) the total land area required to sustain a city can be considered at least ten times larger than the city's own boundaries. Industrialised societies cannot *a priori* be regarded as sustainable, since they extract resources way beyond local geographical carrying capacity by importing goods and services from region in other parts of the world (Wackernagel and Rees, 1996). Reducing environmental impact of certain activities can have a great effect in reducing symptoms in the short run but have harmful consequences through the long-term perspective. It has become important to recognise the scale of events, both the temporal and spatial scale. Sustainable use of resources means evoking "long-term" stability of the interaction between the society and the natural environment. That can only be done when taking into account the overall resource metabolism of the city, to what extend it expands geographically and what kind of resources are being utilised, and its renewability. It implies that there is a need to keep certain transparency between the design of dwellings, its use, and overall impact on resource utilisation. In such terms material efficiency of buildings and their use become a centre focus for planners in terms of forecasting energy use, natural resource use and durability.

1.1 Ecological living

Creating alternative form of living is seen as one of many means towards sustainable living. Swedish homes can be considered as typical households of a post industrialised society. In Sweden, much is debated on what measures are necessary to reduce the environmental impact of Swedish households. Large shares of these discussions have dealt with "ecological living", the importance of building "ecological houses" (eco-houses) and "living ecologically" (eco-living) (Berge, 1992; Bokalder and Block, 1997; Malbert, 1994). Policy makers are often faced with the dilemma of choosing between different planning options that do not clearly demonstrate the environmental perspectives involved. This is understandable since the underlying processes concerning eco-living are complex and not well known.

The principal idea of eco-living is "self-sufficiency" of materials for constructing a dwelling and vital necessities for living. It involves a change in lifestyle from being a total receiver of resources towards production and recycling of resources. People living by ecological principles extract their own water, grow own food products and utilize local energy source as well as other materials needed for self sustainment (Boverket, 1992; Gunther, 1989; Gunther, 1995). Building ecologically involves choosing alternative building materials that occur frequently in nature, are easily recyclable and have minimum health impacts (Boverket, 1992).

1.2 Quantifying ecological living

Quantifying ecological living can be twofold, focusing on material use into dwellings or the household lifestyle. Numerous studies (Berge, 1992; Berge, 1995; Lundblad and Paulsen,

1996) have been conducted on the environmental impact of building materials, based on the Life Cycle Assessment principles, focusing mainly on the material cycle and its recycle and efficiency. Designer and architects have used these studies to improve dwellings and their performances. Similarly has focus been drawn up on minimisation of household waste, energy efficiency and alternative sanitation treatment methods, such as dry sanitation, artificial wetlands and recycle of domestic waste (Ashley et al., 1999; Fittshen and Niemczynowicz, 1997). These studies analyse and describe material flow through the dwelling material cycle but often lack description on the household lifestyle or the combination of both. Several studies (Lindén, 1997; Nonami et al., 1997)have focused on ecological lifestyle of dwellers, but in a more moral or ideological sense where the attitudes and awareness of involved inhabitants are mapped to reflect on recycling consciousness, choice of products and transport use. Little has been done on quantifying lifestyle in the term of energy intensity and its impact on a national and global level. Furthermore has little work been done on combining the two concepts, ecological impact of building materials and the household consumption.

The Ecological Footprint (EF) is "a one dimensional" projection of several dimensions of sustainability, energy, mass, structure and time into area. The collapse is stepwise and can principally be stopped at any level in the down scaling process. This study combines the two concepts by quantifying the energy and material needs required to construct a dwelling and the energy used for living.

2.0 The case studies Toarp and Oxie

The design of Toarp followed the definition given by Boverket (1992). The total area is 4.2 hectare, and the village consist of 37 houses, which are positioned on south directed slope. The houses are constructed from "ecological" 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 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 (Wiberg, 1998). At the start of the operation, the houses where installed with dry sanitation (composting) toilets, but the inhabitants faced major technical and operational problems since the composting toilets where installed without sufficient knowledge and direction for use. About half of the composting toilets were exchanged for water toilets. The water toilets are connected to a root zone system and the sludge is collected by a local farmer. The composted excretory product from the dry sanitation toilets is utilised by the inhabitants themselves (Fittshen and Niemczynowicz, 1997).

Oxie is a normal south Swedish suburban area. It is chosen as a reference area since it is situated next to Toarp. Oxie is connected to the national electric grid and to the municipal water system. Most of the houses in Oxie are heated by electricity but some are equipped with 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, comparable to the eco-village. Houses in the reference area had to be similar to Toarp regarding; size, garden area, family structure and transport distance to Malmö city. An area called Kyrkby in Oxie was suitable for the purpose and two streets lying close to each other "Pilevalsvägen and Bäckarängsvägen" were chosen for the analysis. The area can be considered as typical Swedish households with typical Swedish consumption pattern.

According to Lindén (1997), the lifestyle in Toarp is very similar to the western urban lifestyle in terms of transport, buying necessities, goods etc. What is contrasting in Toarp compared to the normal Swedish lifestyle, is the tendency towards more "family centred" and cooperation between other groups, and more “time-consuming” lifestyle. Furthermore is the tendency towards living that requires more manual handling (Lindén, 1997).

3.0 Methodology

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 house*. A sensitivity analysis of energy use space heating in different housing options.
B. *Ecological Footprint analysis (EF)* 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.

3.1 Lifecycle inventory of Toarp and Oxie

This assessment was conducted by using *lifecycle inventory* 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 pers.comm.). Information on the house form Toarp was obtained from PEAB AB (Larsen 1998 pers.comm.). The basic phases for building a house were identified and system boundaries were drawn around three basic factors;

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 and 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 and 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.

3.1.1. Calculating energy to land

In evaluating the energy for different processes, the report from Berge (1995) is giving 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 are 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 and 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 (Wackernagel and Rees, 1996). Thus the land required to sequester CO_2 from one nuclear energy unit equals one coal energy unit. A 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. 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 and Bruno, 1996).

3.2 Ecological Footprint analysis on Toarp and Oxie

A standardised method, developed by Wackernagel & Rees (1996) was used to compare the consumption levels of the two housing areas, Toarp and Oxie. 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. After collecting data on consumption from a normal household, the data was calculated with a program called *"Footprint calculation matrix for households"*. The annual footrprint values were estimated for every household member. Thirty-five 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

A simulation on the ecological footprint was carried out by using the results obtained from the households in Toarp and Oxie. The six main consumption categories in the *"Footprint calculation matrix for households"*: *food, housing, transport, goods, services and waste,* where simulated.

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. Implementing reduction strategies concerning energy use, alternative consumption pattern and transport means can substantially reduce the footprints in households.

3.3.2 Model description

The model consists of two parts, the first represents the *fair Earthshare*, and the second represents the Swedish national footprint. The *fair Earthshare,* which is 2.2 ha/capita, is the world total available biologically productive land area and sea space per capita in hectare shared equally between every person on the globe Wackernagel & Rees (1996). The national footprint is divided into six "sub-categories", which represent different aspects of the footprint, 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, which was the value per capita at the year 1900.

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 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:

1) **Footprint projection-** According to Wackernagel and Rees (1996) the footprint of the industrialised 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. Meadows 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.
2) "**Eco- capacity"-** According to FAO data (FAO, 1998) world population is expected to reach 9.4 billion by 2050 and stabilise around 10 billions in following decades thereafter. According to Wackernagel et al. (1998) the available amount of all ecological productive land on Earth per person is today 2.2 ha. This is known as *fair Earthshare.* 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.
3) 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 (lighting and appliances 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.

4.0 Results

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

This study extracted two types 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. All energy values were converted to "the" hectare forest, corresponding area that can produce the energy according to Wackernagel´s methodology (Wackernagel and Rees, 1996). 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 $\sim 80\ Gj*ha^{-1}*year^{-1}$ 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, data from Berge (1995): Bygningsmaterialer for en baerkraftig utvikling, NKB. Numbers are in $MJ*kg^{-1}$ 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). PM- refers to "primary material" or the raw material.

KWh/ ton transport- According to Berge (1992) the energy consumption ratio per unit transport is following: $kWh*1000kg^{-1}*km^{-1}$, large trucks 0,5, trucks w/(trailer) 0.30-0.35, electric trains .11-0.13, Freighters 0.17, Flight 9.8.

Transport distances and transport methods of the building materials are from Berge (1992) and Adalberth (1999).

CO_2 g*kg material^{-1}*ton CO_2 transport^{-1}- calculated from Berge (1992), Berge (1995) and Bertilsson (1995).

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 (80 $Gj*ha^{-1}*year^{-1}$)**.**

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 tons 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 tons/ha is used. Data is from Bertilsson (1995).

Data on the south Swedish standard house was given by Bertill Anderson at Skanska AB Malmö, 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, this particular house is $115.6m^2$ (Larsen 1998 pers. comm.).

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 and 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. The answers were run through the *Footprint calculation matrix for households*, for calculations. The average family size in the households were 3.9 persons in Toarp (20 adults and 19 children) and 2.1 persons in Oxie (20 adults and 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 used. 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).

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 ha*y^{-1} Oxie: 3.9 ha*y^{-1}.

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. There was no significant statistical difference in lifestyle between the Toarp and Oxie areas (Mann-Whitney U-test, Z=,n=10 p=0.05). Toarp had an average of 3.7 (SD=1.2) and Oxie an average of 2.8 (SD=0.8).

4.2.3 footprint values

The following figures reveal which categories of the household consumption differ in both villages.

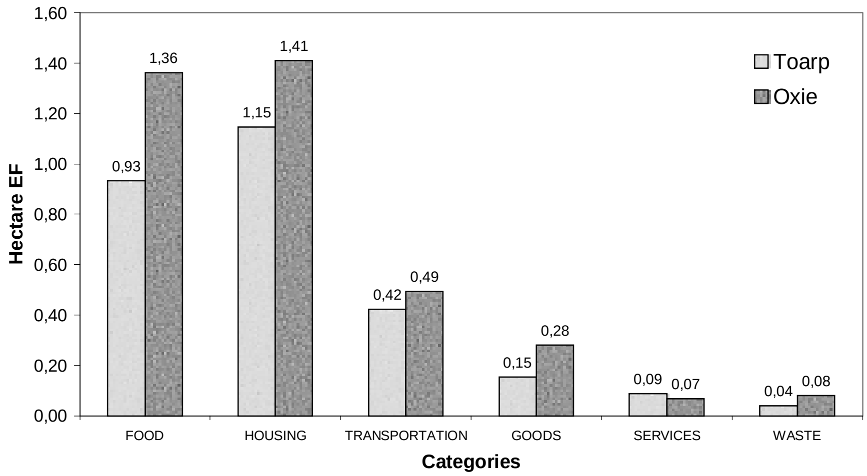

Figure 1: The average footprint in hectare **per person** from each consumption category in both villages.

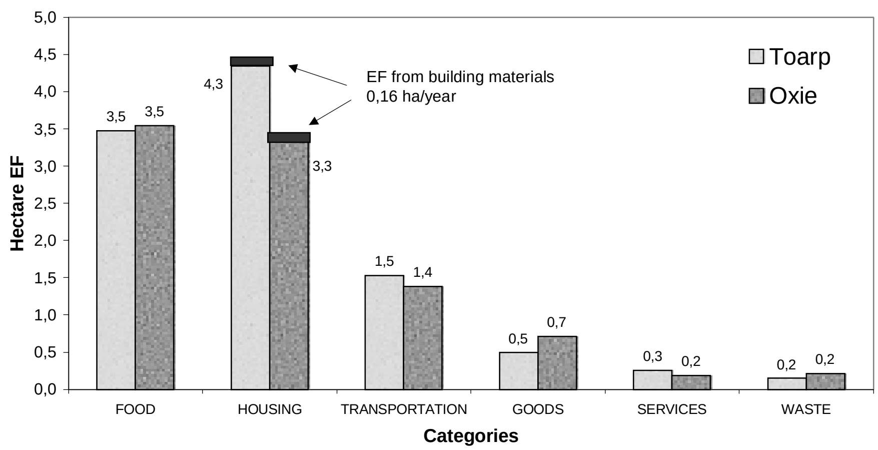

Figure 2: Annual footprint in hectare **per household** is compared between the towns.

The largest difference between the villages is the food category (figure 2). 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. If we compare the footprint *per household* (figure 2) 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).

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 4 presents the average value calculated from Toarp and Oxie. The mean value was used to simulate the Swedish footprint.

Table 4: 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 4 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 3: ***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).

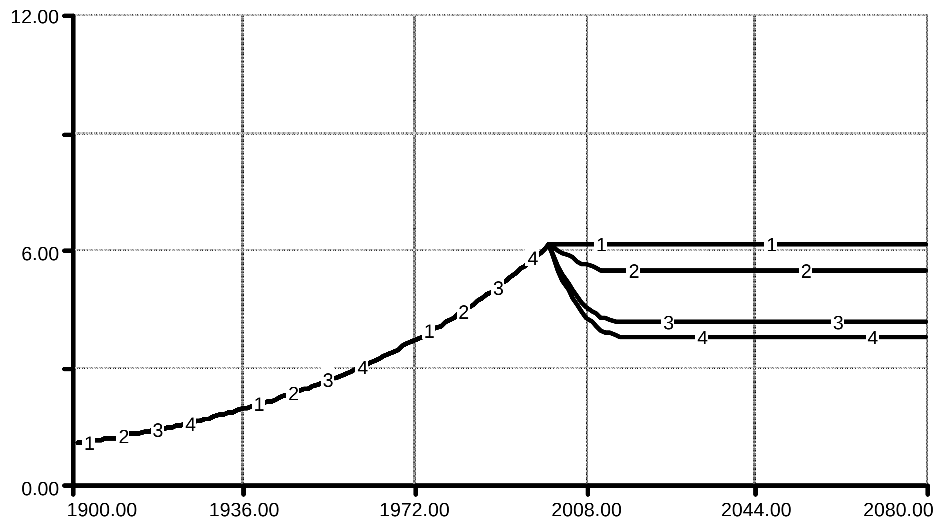

Figure 4: ***Scenario 2- Reduction potentials in households.*** This diagram presents what potentials there are for decreasing the footprint. ***Line 1*** shows the footprint level as it is today. ***Line 2*** shows the footprint level after reducing meat consumption in households by 50%. ***Line 3*** 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%.

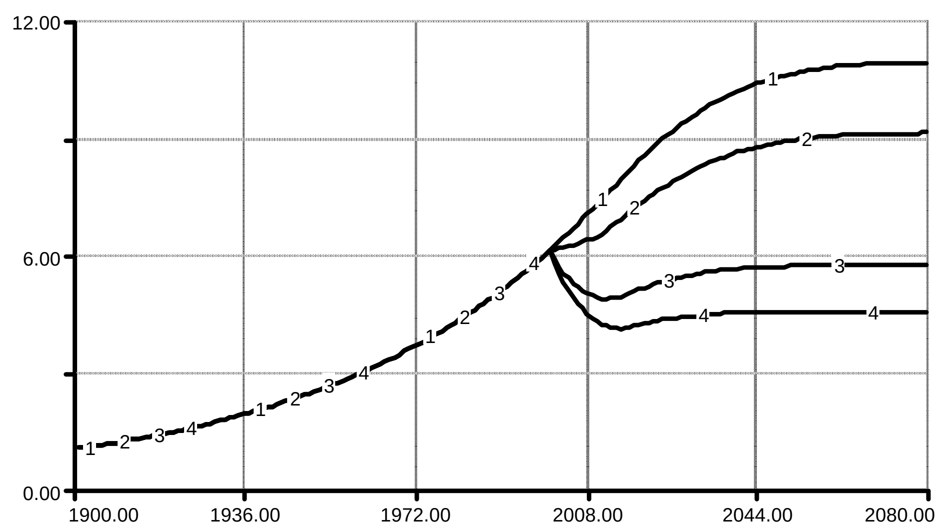

Figure 5: ***Scenario 3- Household scenario.*** Different implementation strategies are tried for households. ***Line 1***, is unchanged scenario. ***Line 2*** is 50% decrease in meat consumption over a fifteen-year period. In scenario ***Line 3***, same as no 2 but also the energy use in the housing 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.

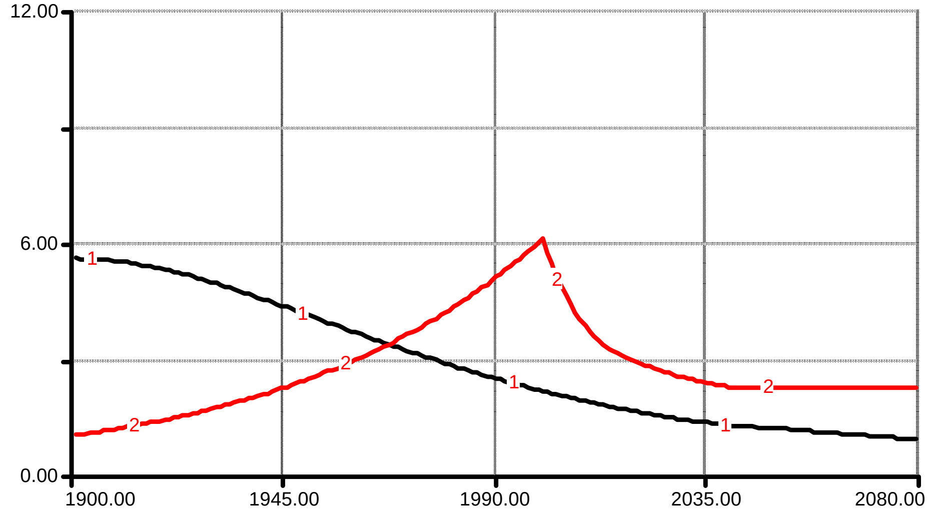

Figure 6: ***Scenario 4- Governmental, industry 50% and household, 70%.*** In addition to the energy and consumption savings made by the households (total 70%), the governmental and industrial sector reduces its footprint by 50% These changes are stretched on a time period of 40 years. Note that the 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***).

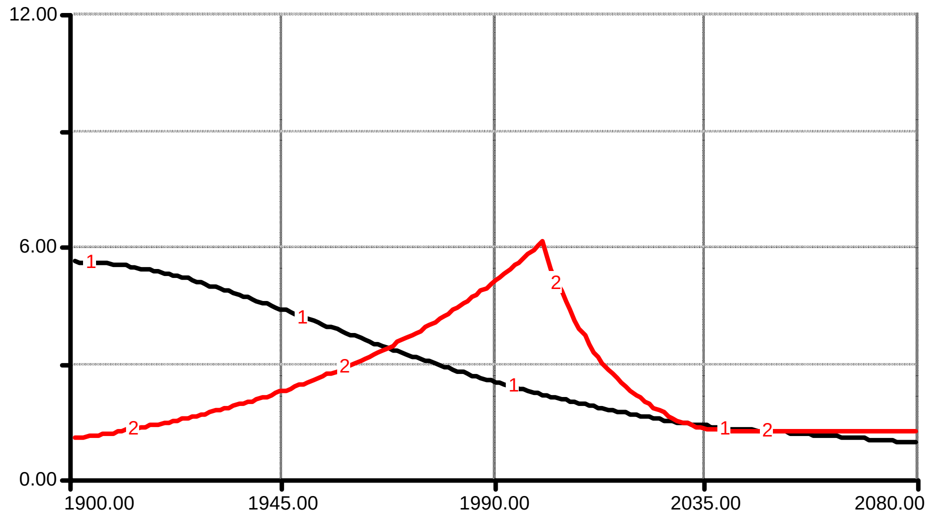

Figure 7: ***Scenario 5- Government, industry 90% and household 70%.*** In the idealistic scenario, the governmental and the industry sector implements factor 10 policy which would lead to reduction of footprint by 90%. This scenario will reduce the over all footprint of Sweden by 85% and probably only 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***).

5.0 Discussions

5.1 Comments on the construction phase

The construction phase contributes less than 5% of the total footprint flow in Toarp and Oxie, given that the footprint level of the household will hold constant through the lifetime of the house. According to Berge (1992) the total energy needed to construct a conventional 100m^2 house is between 360 and 540 kWh/m^2 in Scandinavian climate. Although the lifecycle inventory covered only 10 building materials and only energy and CO_2 emissions, the results fall well within Berge's (1992) definition on energy intensity in housing construction (Toarp house 403 kWh/m^2 and standard house 509 kWh/m^2). The difference between the two houses is 106 kWh/m^2, which can be related to the quantities of plastics used in the standard house (see table 1). Constructing an eco-house requires larger quantities of materials such as bricks and expanded clay blocks, but the total energy needed to produce the building materials is still 20% lower than from the standard house. Using plastics is very energy intensive, and this raises the total energy needed for the standard house and as a consequence its footprint value.

Building ecologically is rather recently occurring in Sweden. The technology associated is more expensive than conventional methods. Much of the 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 could result projects to be economically constrained and limited in their environmental performance. According to Lundbeck (1991), most projects that are ecologically oriented have not been supported financially by the government similarly to conventional building projects. In Sweden most community housing projects are tenancy right oriented which strains the entrepreneurs expenditure on projects. New alternative methods require experience that may prove costly in the beginning especially if they are technologically oriented. Making economic tradeoffs for lower building costs is beneficial for the entrepreneur and the consumer but not the environment. To some extend this could explain why there is currently so marginal difference in the footprint between ecological and conventional building processes.

5.2 Footprint analysis

Comparing the ecological footprint between Toarp and Oxie reveals the following: The difference per person (figure 1) between the households is explained by more people residing per household in Toarp than Oxie. It is observed in figure 3 that both households have similar footprint distribution, which could indicate that the consumption pattern is fairly similar in both places. Even if households in Toarp use 50-70% less electricity than their neighbours in Oxie, they still generate larger footprint in the housing category (figure 2). This difference can be explained by the extensive use of firewood for space heating in Toarp. The Swedish national electricity grid provides space heating and lighting in Oxie. Using wood for space heating generates larger footprint than using electricity produced by hydropower (Wackernagel and Rees, 1996). This alone increases the footprint of the Toarp households by ~23% compared to Oxie (figure 2). If the footprint from the building materials is included in the housing category the footprint value is slightly higher (see figure 2).

The most important consumption categories are the food and housing categories. They represent 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. Goods, services, and waste amount for 11% of 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 are very inefficient in terms of footprints. It would be recommendable to switch to renewable energy sources, increase efficiency, or increase dweller per m^2 house. If the footprint from the building materials is included in the housing category the value is increased by 5%, which is low compared to the lifestyle.

The six simulation scenarios 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.* 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.

It is likely that the Swedish footprint will not develop to 11-12 hectare per capita. Actually such discussion is irrelevant for the modelling purposes, since the model shows the potentials in decrease of the Swedish footprint. If Sweden will develop high consumer, it will be much harder to reduce the footprint than if a lower economic development course is taken. In that sense the model can be used to predict certain scenarios 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 (Cowell and Clift, 1996; Wackernagel and Rees, 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, 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

there is no significant 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 pers. comm.) 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.

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 Gunther (1995) 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.

The study concludes that no significant difference exists in the ecological footprint between the ecological living and the conventional living in the form as presented today in Sweden.

6.0 Refernces

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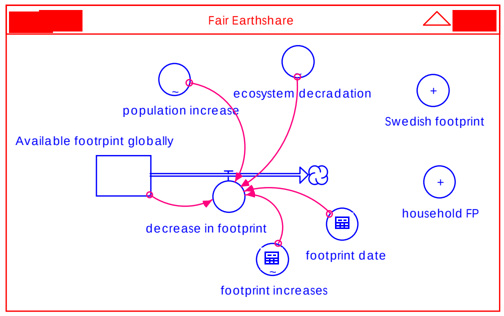
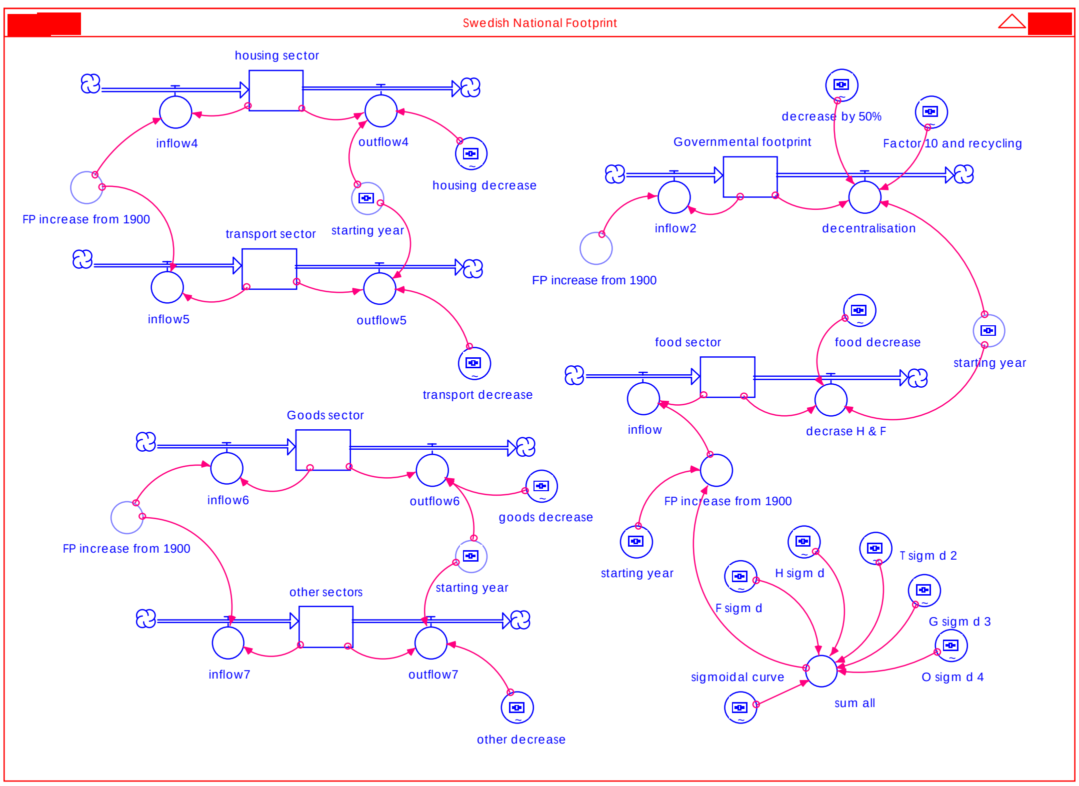
Appendix I: Model preferences





Appendix II: 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)