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The Ecological Footprint of the City of Oslo – Results and Proposals for the Use of the Ecological Footprint in Local Environmental Policy

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Report

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INTRODUCTION

The Western Norway Research Institute in Sogndal and ProSus[1], at the Centre for Development and the Environment, University of Oslo, have carried out a project for the municipality of Oslo with the goal of calculating the city's *ecological footprint* based upon current levels of consumption: *the Oslo Project*. The project description was formulated thus: "*The object of the project is to calculate the ecological footprint of Oslo. The footprint should be calculated for both the public and private sectors providing a total footprint for all the activity within the borders of the city. The footprint analysis should also provide the average footprint per inhabitant of Oslo."*

The background for the Oslo Project consists of three components: (1) the auditing of the city's "Eco-city Program" and the development of a new *State of the Environment Report* for the municipality of Oslo; (2) the municipal efforts on *Local Agenda 21* and (3) the municipality's participation in the "European Common Indicator Project" (ECIP).

While the Oslo Project was underway, the municipality asked the Western Norway Research Institute and ProSus to establish a cooperative relationship with ECIP, which resulted in, amongst other activities, a workshop in Oslo: "The Oslo Workshop on Ecological Footprint" (August 2001). This seminar was a joint effort between ProSus, the Western Norway Research Institute, Ambiente Italia[2] and ENSURE[3]. Researchers as well as representatives from European cities concerned with the calculation of ecological footprints participated. A key issue was the development of an ecological footprint approach within the European Common Indicator Project. At the seminar, a consensus was reached concerning the need to develop a more standardised method for the local application of national footprint calculations presented by the World Wide Fund for Nature (WWF) in their Living Planet Report - The Footprint of Nations (FoN). Further work on this is headed by the consultant firm Best Foot Forward.

Given the absence of a standardised method for the calculation of local footprints, we have developed our own approach for calculating Oslo's ecological footprint. We have studied previous attempts to develop and adapt the footprint methodology for calculations on the local level; primarily, efforts made in *Finland* by the Association of Finnish Local and Regional Authorities (Hakanen 1999)[4] and projects carried out in the *UK* by Best Foot Forward[5]. Efforts to calculate local footprints have also been carried out in *Santiago de Chile* (Wackernagel 1998), municipalities in *Sweden* (Lewan 2000) and municipalities in *the Netherlands* (Del la Coert 2000). In developing our methodology for the Oslo Project, we have also drawn on our experiences in conducting similar work for the municipality of Stavanger, in connection with the municipality's preparation of an energy and climate action plan (Farsund et. al. 2001). In contrast to the approach developing within the framework of

[1] Program for Research and Documentation for a Sustainable Society.
[2] http://www.ambienteitalia.it/
[3] European Network for Sustainable Urban and Regional Development.
[4] The Association of Finnish Local and Regional Authorities has made its own calculation model (Excel-based), which means that the municipalities can easily conduct their own footprint analysis, given a certain minimum of data collection done locally ("Ekolginen jalanjalki").
[5] See examples from Oxfordshire County (http://www.bestfootforward.com), City of London (www.citylimitslondon.com) and Isle of Wight (http://www.bestfootforward.com).

ECIP, we have chosen a *bottom-up* approach, where the footprint is calculated on the basis of available local data. Where such data has not been available, we carried out our calculations by substituting national per-capita data adjusted to Oslo levels.

In the following chapter, we provide a more detailed description of some of the principal methodological choices upon which our work is based, as well as a detailed account of how we have collected and analysed the data for Oslo. We also present the (actual) footprint analysis, and discuss some possible areas in which municipal ecological footprint analysis could be applied.

METHOD FOR CALCULATING THE ECOLOGICAL FOOTPRINT

The ecological footprint: methodology

The *term* ecological footprint was co-originated by William Rees and Mathis Wackernagel of the University of British Columbia, Canada, in the early 1990s[6]. An ecological footprint may be regarded as a method, an indicator, as well as a tool. It is a *method* of calculating and evaluating the environmental impact of the consumption of goods and services. The unit of measurement which is used is the consumption of biologically productive land, measured in hectares. An ecological footprint is also an *indicator*[7]*;* by means of a figure in hectares, it provides a simplified representation of important environmental impacts from different types of consumption. An ecological footprint can also be used in various contexts and for different purposes as a *tool.* For instance, it can be used as a tool for environmental impact assessment when considering different alternatives in a political/administrative decision-making process, or for annual reporting on the state of the environment in a municipality.

The fundamental understanding behind the concept of the ecological footprint is that the Earth's land area is of an absolute and limited magnitude, whereas the number of human beings is increasing, as well as the use of land associated with all human functions. All human functions require the use of land - primarily biologically productive land, on both local and global levels. This includes land used for buildings and roads, the production of energy and material resources, food production, and land required for waste-disposal and the absorption of emissions. The collective impact of this land consumption determines the limits for our local functions. The following categories of biologically productive land are used when calculating the ecological footprint (Chambers et al. 2000):

1. Biodiversity land
2. Bioproductive land, using the following three sub-categories:
   a) Arable land
   b) Pasture land
   c) Forested land
3. Bioproductive sea space
4. Built land
5. Energy land

In an ecological footprint analysis the land necessary for the protection of biological diversity is often set at 12 per cent of the total consumption of land, according to

[6] E.g. in Wackernagel and Rees 1996: Our Ecological Footprint. Reducing Human Impact on the Earth, Philadelphia, USA: New Society Publ.

7 The ecological footprint is, in reality, an index. Indicators must in some way or another build on basic quantified data. *Indexes* are actually higher up in the hierarchy. They are based on indicators, and relate to these as indicators relate to basic data. Normally, an index should be both a simplified and a quantified representation of a complex of several indicators (Høyer and Aall 2002).

recommendations from the World Commission's report "Our Common Future" (1987). In other words, 12 per cent of the calculated footprint is added to the total in order to obtain a figure that specifies the global responsibility for protecting land. *Bioproductive land* represents the area needed to produce various consumer goods such as food (arable land and pasture land), cotton (arable land) and timber (forested land). Correspondingly, the *bioproductive sea space* is the area needed for the production of fish. The consumption of bioproductive sea space presents a methodological problem. In more recent footprint analyses, however, sea space is included. The total fishing production related to productive sea space is roughly 33.1 kg fish per productive hectare sea space (WWF 2001). *Energy land* is the hypothetical area needed to maintain a sustainable energy consumption and supply, and usually represents the forested land needed to absorb the related CO_2 emissions. The method does not, however, define forest planting as a climate policy measure, but uses the conversion to forested land to illustrate the hypothetical area required to facilitate comparison with other types of consumption. An alternative approach would be to calculate the area in terms of bio-fuel (for example "energy forest") needed to replace the amount of energy which today is produced from fossil fuels. Both approaches result in roughly the same hypothetical area needed (Holden 2001). *Built land* is the area needed for buildings and roads, and where the bioproductive capacity is or will be lost (Chambers et. al. 2000).

Per capita ecological footprints have been calculated for 150 countries in "Footprint of Nations" (FoN) – published in WWF's "Living Planet Report 2000"[8]. Calculations have been made for roughly 175 consumption categories for each country, by using net national consumption figures based on national trade and production statistics (i.e. national production - export + import). For the rich nations, the report calculates a footprint which far exceeds that which would be possible in terms of bioproductive land capacity for the world's population as a whole. Rees and Wackernagel (1996) have estimated that on a global level, about 2 hectares of land are accessible to each world inhabitant, while the living standard of the West today corresponds to a footprint of 4-6 hectares per capita. If all of the world's inhabitants were to consume the same quantity of biologically productive land as currently do the inhabitants of the rich part of the world, then three additional planets would be needed to meet the demand.

The calculation method in FoN represents a top-down approach - *the compound approach* - where analysis of a country's footprint is converted into an average per capita figure, with the aim of including a society's total activities and functions, based on national data. A footprint can also be calculated by analysing individual functions and *components* of consumption, a bottom-up approach, which limits the analysis to certain kinds of impacts on the environment. This is often referred to as *the component approach* (Chambers et al. 2000), where the footprint for different activities is calculated in advance. Thus, the ecological footprint can be used to analyse products, production processes, activities, as well as communities and countries as a whole, all depending on which methodological approach is chosen.

At the same time one must be aware of the *weaknesses* of the footprint methodology. It is difficult to include problems related to chemicals, heavy metals and radioactive substances in footprint analyses, using the current methods. This also applies to the quality of the environment and the consumption of water. The potential of double counting is another key weakness. Nevertheless, the most crucial weakness seems to be the methodological

[8] See http://www.panda.org/livingplanet/lpr00/

problems emerging from so many different kinds of environmental impacts being converted and reduced to one *single* unit: the hectare (Høyer 2002). This consideration often forms the basis for criticism of the method and the results deriving from it. One way in which to reduce this problem is to focus on the consumption patterns and environmental impacts identified in footprint analyses, rather than discussing the absolute figures.

How to calculate a local ecological footprint?

The compound approach calculates the footprint of the *end consumption* (Rees and Wackernagel 1996). For this reason, the production in itself is not footprinted, as this could easily lead to *double counting.* All consumption of energy and resources involved in the production of goods and services and the treatment of waste follows in principle as an "ecological rucksack" to the products and services being consumed.

In footprint analyses on a national level, *production* must of necessity be ignored; but it should not necessarily be neglected when making analyses on the local level. This can be attributed to two conditions:

- *Methodologically speaking,* local produce is not necessarily exclusively consumed locally; consequently, the problem of double counting does not always occur in practice.
- *Pragmatically,* because environmental problems related to local production are often important issues on the local policy-making agenda. It would therefore seem strange not to include local production, when calculating a local ecological footprint.

Footprint analyses of production are in principle similar to footprint analyses of consumption, in the sense that one calculates the footprint of a company's consumption of energy, goods and services in addition to the built land the company occupies. However, a range of practical problems is encountered when including local production in a local footprint analysis. As mentioned, there is the danger of double counting. In principle, a deduction should be made for local consumption of locally produced goods and services, but in practice this might be difficult to determine. A more significant argument for not including local production in a local footprint analysis is that it would involve *considerable effort* to collect the consumption data for each separate company. One possible practical approach is to limit the required data to the following three categories (for which data collection is relatively straightforward in Norway):

- The built land occupied by companies within the municipality's borders
- The consumption of *electricity* within the municipality (separated into public and private sector consumption)
- The emission of *greenhouse gasses* by public and private sectors[9]

The footprint analysis would be further simplified, if no consideration were given as to whether the local produce is consumed locally or not. Further, companies' consumption of input factors other than energy and built land would not be considered. Within these limitations, calculations would normally be relatively manageable, and would also satisfy the local requirements of including local production in local footprint analyses.

[9] See http://www.sft.no/arbeidsomr/prosjekt/klima/verktoy/klimakalkulator/.

Where there are waste treatment facilities, waste treatment can also be considered as a type of local production. As with local production, the question concerning waste treatment is often an important one in local environmental policy debates, which suggests that waste might be better treated as a separate category in local footprint analyses. More specifically, it is the *impact* of waste treatment which should be included in the footprint. The impact of the actual waste, i.e. the physical consumption that the waste represents, has already been included as part of the "consumption". An important condition which differentiates waste treatment from production is that the former can, in principle, provide a *reduction* of the footprint. This occurs with the re-use, recycling and energy recovery of waste. Also in the case of waste, it might be argued that we should limit the analysis to the occupation of built land, emission of greenhouse gasses from landfills and consumption of energy.

National footprint analyses are only concerned with the consumption that occurs within *borders of a country*. Analogously, a similar limitation could be adopted locally. In other words, only the consumption that occurs *within* the borders of the municipality would be considered. However, such a delimitation may seem unreasonable; in municipalities with a limited geographical scope, a large portion of the inhabitants' consumption of transport will not be included in the analysis. It therefore seems reasonable that their personal transport occurring *outside* the borders of the municipality should also be included. This can be simplified in practice to include *transport* that local inhabitants consume outside the borders of a municipality. Considering that the footprint analyses have an explicit individual focus, this is a crucial choice which would influence the further application of the results[10].

National footprint analyses are to a large extent based on trade statistics in tons and value. Analogous local data is only found to a limited degree. For this reason, other types of data sources would usually be used for the calculation of local footprints. We might differentiate between two main approaches to the collection of local data:

- *The top-down* approach: relies on using national average figures for consumption per capita and, as far as possible, deriving proxy data for the local consumption per capita, using local and regional data adjustments
- *The bottom-up* approach: relies on genuine local or regional consumption data

In practice, the *combination* of a top-down and a bottom-up approach will be the most realistic to use in an ecological footprint analysis at the local level. Local consumption data will be used whenever possible, either directly or for the adjustment of national consumption data. Where no form of local or regional consumption data exists, national consumption data must be used directly.

The national footprint analyses within FoN operate with approximately 175 items. It would prove difficult to collect local data of an equivalent extent. A practical modification, in local footprint analyses, would be to *reduce* the amount of data that is included in the analysis. When footprinting the consumption of the households, it would be relevant to focus on the items that are considered the most decisive for the outcome of the analysis. Several studies

[10] For example, the NPC's so-called "climate calculator", which provides figures for the emission of greenhouse gasses at the municipal level, does *not* follow this principle. It only provides figures for the activities that occur *within* municipal administrative borders. This can sometimes lead to peculiar results. For instance, municipalities that deliver their waste to a neighbouring municipality will have zero emission of methane from landfills, while the host municipality will have the cumulative impact incorporated in their own climate calculation. Calculations of emissions associated with air transport are only made for municipalities with airports, and then for all the passengers. However, only emissions that occur within 100 metres of ground level are included; in other words, only those resulting from take-off and landings. All other emissions are calculated as occurring outside the limits of the municipality (Groven 2001).

suggest that three components; 1) consumption of food, 2) energy consumption of transport, and 3) consumption in relation to housing, may represent as much as 75 per cent of a household's total energy consumption (Naturvårdsverket 1996; Vittersøe et. al. 1998; Lorek and Spangenberg 2001; Holden 2001). In our calculations we have used the three components mentioned above - food, transport and housing - as a basis, so as to limit the amount of data required in the footprint analysis. Data on transport and housing should be relatively simple to collect, but for the consumption of food, it will often be necessary to derive proxy data from national per capita averages. *If* local collection of data were attempted in a local footprint analysis, e.g. through surveys, then collecting data on food consumption would be the most cost-effective.

The footprint analysis of Oslo

The collection and processing of data has been done in five steps:

1. Determination of which components and sub-components of the local consumption should be included in the calculation.
2. The collection of *local* consumption data.
3. Finding *national* consumption data, where local data is not available.
4. Finding ways of deriving proxy data from the national data in (3).
5. Conversion of the consumption data to ecological footprint.

As suggested in the previous chapter, we have grouped the consumption data and following footprint analysis of Oslo under the headings "local production", "waste treatment" and "household consumption".

Consumption data for local production

For *local production* we have included the following components, where we have differentiated between the private and public sectors:

– The direct land-use for buildings in the public and private sectors
– Emission of greenhouse gasses from stationary combustion and processing facilities
– Consumption of electricity

We obtained the *direct land-use* from the land-use statistics for the municipality of Oslo. Figures for emissions of greenhouse gasses were taken directly from the Norwegian Pollution Control Agency's "climate calculator"[11]. We obtained figures for *consumption of electricity* after much ado, from the local electricity supplier. We have encountered problems in obtaining reliable data on local energy consumption on the Oslo Project, as have similar projects abroad. The increasing privatisation of the energy sector complicates the collection of reliable data, as it is often the companies themselves who determine the guidelines for public access of information (Simmons and Lewan 2001; Teigland and Aall 2002).

[11] See http://www.sft.no/arbeidsomr/prosjekt/klima/verktoy/klimakalkulator/.

Consumption data for households

As mentioned above, in footprinting the household *consumption* we wanted to reduce the amount of data needed by concentrating on the components in the footprint analysis which we considered to be of the greatest importance: the consumption of food, transport and housing. A more detailed delimitation was then made by considering the indirect energy consumption in Norway (Farsund et al. 2001). In addition, we also decided to include the consumption of goods, by focusing on the sub-components: “clothes and shoes” and “leisure goods and services”, considering that they collectively represented a relatively large segment of the total energy consumption, particularly since the consumption of these components has increased in recent years (Farsund et al. 2001). Within the area of goods, we also considered the consumption of paper. Although paper energy does not represent a large part of the footprint analysis, it is associated with a relatively large use of bioproductive land (forested land).

Housing-related consumption has been divided into the following sub-components:

- direct land-use for housing
- embodied energy in housing, furniture and other equipment (indirect energy consumption)
- consumption of lumber for housing
- consumption of energy for housing, sorted by fuel type; electricity, heating oil and firewood (direct energy consumption)

The direct land-use figure for housing must not be confused with the living area of each housing unit, which is the total floor area in each housing unit, often distributed over several floors.

Embodied energy means the energy which has been consumed in the production of housing, furniture and equipment. As a basis for these assessments, we use the analysis of indirect energy consumption published in “Sustainable Norway – Probing the Limits and Equity of Environmental Space” (Hille 1995). Indirect energy consumption is calculated as emission of CO_2.

Lumber consumption is calculated on the basis of national figures, which give a 1.6 m^3 per capita annual consumption (Hille 1993); assuming that 80 per cent is associated with the construction of new housing.

As mentioned above, the electric-power consumption data was obtained from the local supplier, while the data for the emission of CO_2 from *domestic heating oil* has been found in the Norwegian Pollution Control Agency’s “climate calculator”. The consumption of *fire wood,* however, proved difficult to calculate; working with a number of different sources, both national and local, we obtained highly inconsistent figures, varying from 200 kWh to 1500 kWh average annual consumption per household. Our final analysis is based on proxy data.

The consumption of *transport* is sorted into the following three sub-components:

- direct land-use for transport
- emission of CO_2
- electricity consumption

Examples of *direct land-use for transport* are roads, parking lots, railway tracks, airports etc. The Western Norway Research Institute has in a previous study calculated the land-use for transport in relation to *passenger-kilometres* (passenger-km) for various types of transport (Aall 1992).

The basis for calculating land-use, CO_2 emissions as well as the consumption of electricity is completed passenger-km, which is then multiplied by the appropriate factors. The Western Norway Research Institute has in an earlier study for Oslo Sporveier (a transport company in Oslo) (2001) calculated passenger-km figures for private cars, taxis, subways, trams, buses and boats. The footprinting of air transport is based on proxy data derived from a study carried out by the Western Norway Research Institute for the Ministry of Transport (Lundli and Vestby 1999).

The national consumption data for *food* is of little use for our purpose, so, to a high degree, we have derived our own proxy data. The consumption of food has been divided into the following components:

- indirect energy consumption (embodied energy)
- emissions of greenhouse gasses (methane from animals and nitrous oxide from the production and use of fertilizers)
- direct land-use (built, arable and pasture land)
- consumption of bioproductive sea space (fish)

For the calculation of the indirect energy consumption and emissions of greenhouse gasses we have used calculations done in connection with a project for the municipality of Stavanger (Farsund et al. 2001). The *indirect energy consumption* or embodied energy in food represents the energy used for the production, manufacture and distribution of food. The figures for embodied energy are converted to emissions of CO_2, presupposing an emission figure corresponding to 79 kg CO_2 per GJ (Farsund et al. 2001). The emission of *methane* from Norwegian agriculture was in 1997 estimated at 108,000 tons and *nitrous oxide* at 8,400 tons (SSB 2000). Production of nitrogen fertilisers resulted in an emission of 4,800 tons, Approximately 15 per cent of this production was sold to the domestic market. In other words, the emission of nitrous oxide due to Norwegian agriculture can be estimated at 9,100 tons. With a GWP-factor for methane of 21, and 310 for nitrous oxide, the methane emission from Norwegian agriculture is equivalent to 2.3 million tons CO_2, and the nitrous oxide emission is equivalent to 2.8 million tons CO_2. In addition, there are emissions due to imported agricultural goods, although, in this case, the figure for methane is probably small. Globally, the emission of methane is to a large extent due to cattle and sheep, as well as rice production. Norway is a marginal net exporter of beef and sheep products, while the import of rice is small. Since they have a lower consumption of fertilisers, the per hectare emission of nitrous oxide from areas abroad, which supply us with agricultural produce, is slightly lower, than from the app. 0.9 million hectare arable land in Norway. In the calculations for the municipality of Stavanger, these foreign emissions are estimated at 1 million tons of CO_2-equivalent (Farsund et al. 2001).

Table 1 Direct and indirect emission of greenhouse gasses annually in relation to Norwegians' consumption of food (Farsund et al. 2001)

Factor	*Emissions*
Indirect energy consumption	8.1 mill. tons CO_2
Emission of methane gas	2.3 mill. tons CO_2-equivalent
Emission of nitrous oxide	3.8 mill. tons CO_2-equivalent

For the analysis of *direct land-use*, we have used the net national consumption (in kg.) multiplied by global yield factors for a selection of food types (those with the largest land-use): *fish and seafood, beef, sheep and goat products, poultry, milk, cheese, eggs, cereals, fruit and vegetables, and soybeans.* Further, we have included estimates of the direct land-use of farm buildings (FIVH 2000).

Under the heading "*goods"* we have included the following sub-components:

- clothes and shoes
- leisure goods and services
- paper (forested land)

For the first two sub-components, we have used national figures on the indirect energy consumption (4.50 GJ per capita for both), converted to emission of CO_2 (Farsund et al. 2001). For paper we have assumed that the consumption of paper corresponds to the annual amount of paper which ends up as waste. In 1999, the national figures for waste show that 1.040.000 tons of paper ended up as waste in Norway, which corresponds to 234 kg per capita[12].

Consumption data for waste

Although we assumed that waste would contribute little to the footprint as a whole, we chose to include it, due to its importance in municipal environmental policy. To establish waste's contribution, and the effect of the various waste treatment initiatives, we divided the calculation for waste into the following sub-components:

- direct land-use for waste treatment (installations and sewage-purification plants)
- stationary energy consumption by waste treatment installations and sewage purification plants
- emission of greenhouse gasses from landfills
- energy production from waste

In the footprint analysis of waste in Oslo, we have chosen to clarify the *direct land-use* in relation to both water and sewage treatment, and waste treatment, taken from the land-use statistics of Oslo. We obtained the emission of *greenhouse gasses* from waste treatment from the Norwegian Pollution Control Agency's "climate calculator".

We have also attempted to highlight the *positive* contribution of waste in the footprint analysis of energy recovery, and the collection of methane from landfills. Although this contribution is small in comparison with the total footprint, the clarification of the positive effects of such initiatives in relation to municipal waste treatment and sewage is, in our

[12] See http://www.ssb.no/emner/01/05/40/avfregnpapir.

opinion, an important aspect of environmental policy. *Methane* collected from landfills can be used for the local production of both heat and electricity. However, it has proved difficult to acquire data on the amount of methane used for energy recovery. Figures were collected after discussions with the various installations, but it was usually difficult to obtain reliable figures. Among the obstacles were losses in the recovery process and determining the amount of energy used internally at the installations (the internal use of energy from the process is now underestimated). Routines for the reporting of this type of energy recovery and consumption seem to be inadequate.

The waste treatment installations in Oslo produce district heating through the combustion of bio-mass and waste. The energy produced is distributed by the local energy supplier. It has been difficult to obtain an overview of the consumption figures for different customer-groups from the supplier in Oslo; of necessity, we have been obliged to derive proxy data based on information from the separate installations.

Local consumption data and proxy data derived from national consumption data

We have managed to use local data for about *20 per cent* of the Oslo footprint. The remaining 80 per cent represents national consumption data, which in various ways has been adjusted so as to generate proxy data representing as “local” data as possible (cf. table 2). All the data is, in one sense or another, *local* - although the individual adjustments have only provided us with approximations of the actual local consumption in comparison with the national averages.

Table 2 Categories and data sources in the footprint analysis of Oslo

Components	*Type of data*	*References*
Local production (public and private sectors)		
– Direct land-use	Local data	Municipality of Oslo
– Energy consumption - electricity	Local data	Viken Energi
– Emission of greenhouse gasses	Local data	NPC's "climate calculator"[13]
Household consumption		
Food:		
– Indirect energy consumption	Proxy data (national data adjusted with figures from Consumer Survey)	Farsund et.al. (2001)[14], SSB[15]
– Methane from animals	Proxy data (national data adjusted with figures from Consumer Survey)	Farsund et al. (2001)[14], SSB[15]
– Nitrous oxide from fertilizer	Proxy data (national data adjusted with figures from Consumer Survey)	Farsund et al. (2001)[14], SSB[15]
– Direct land-use	Proxy data (national data adjusted with figures from Consumer Survey)	Farsund et al. (2001)[14], SSB[15]
Goods:		
– Clothes and shoes	Proxy data (national data adjusted with figures from Consumer Survey)	Farsund et al. (2001)[14], SSB[15]
– Leisure goods and services	Proxy data (national data adjusted with figures from Consumer Survey)	Farsund et al. (2001)[14], SSB[15]
– Paper	Proxy data (national data adjusted with figures from Consumer Survey)	Farsund et al. (2001)[14], SSB[15]
Housing:		
– Direct land-use for housing	Local data	Municipality of Oslo
– Embodied energy in furniture and equipment	Proxy data (national data adjusted with figures from the housing statistics)	Farsund et al. (2001)[14], SSB[16]
– Embodied energy in housing	Proxy data (national data adjusted with figures from housing statistics)	Farsund et al. (2001)[14], SSB[17]
– Consumption of lumber	Proxy data (national data adjusted with figures from housing statistics)	Hille (1993), SSB[17]
– Energy consumption electricity	Local data	Viken Energi
– Emissions from direct consumption of oil	Local data	NPC's "climate calculator"[13]
– Energy consumption fire wood	Proxy data (national data adjusted based on own calculations)	

[13] See http://www.sft.no/arbeidsomr/prosjekt/klima/verktoy/klimakalkulator/.
[14] National calculations carried out in connection with climate plan study for the municipality of Stavanger.
[15] See http://www.ssb.no/emner/05/02/fbu/tab-2001-12-19-04.html.
[16] See http://www.ssb.no/aarbok/2000/tab/t-0503-247.html
[17] See http://www.ssb.no/emner/10/09/byggeareal/index.html

Table 2 Categories and data sources in the footprint analysis of Oslo (cont.)

Components	*Type of data*	*References*
Transport:		
– Private car and taxi	Local data (car ownership) multiplied by county figures for annual driving distances	Road Traffic Authorities , Monserud (1997)
– Boat	Local data	Oslo Sporveier (2001)
– Bus	Local data	Oslo Sporveier (2001)
– Train	Local data	Oslo Sporveier (2001)
– Tram and subway	Local data	Oslo Sporveier (2001)
– Air transport	Proxy data (national data adjusted with figures from air transport study)	Lundli and Vestby (1999), Riden and Stangeby (1999)
Waste treatment (waste and sewage)		
– Direct land-use waste/sewage purification plant	Local data	Municipality of Oslo
– Direct energy consumption waste/sewage purification plant	Local data	Waste treatment installation, purification plant
– Emission of greenhouse gasses	Local data	NPC's "climate calculator"[13]
– Emission saved due to methane combustion	Local data	Own calculations based on data from waste and sewage installations
– Energy consumption and saving from district heating/energy production from waste and bio-mass	Local data	Norsk Petroleumsinstitutt, Viken Energi, our own calculations

We have used exclusively local data for the main components *local production* and *local waste treatment.* With regard to *household consumption*, the most important method for deriving proxy data has been to adjust national consumption data with the aid of Statistics Norway's (SSB) *Consumer Survey*[18], especially for the categories *food* and *goods*. We have compared figures for Oslo and Akershus with national averages for outlay per household in various consumption categories.

Consumption of *food*: using the Consumer Survey, we have compared national averages from 1998-2000 for outlay per household within the categories "food and beverages" (where Oslo has 7.8 per cent *lower* consumption) and "restaurant services" (where Oslo has 40.2 per cent *higher* consumption). Together, these result in a 4.4 per cent higher consumption than the national average. We have used this per cent difference on all the food types within the food component, except for arable and pasture land and the consumption of fish, where we considered the *composition* of the food consumption (see table 3 below). The Consumer Survey provides us with some points of reference here, since the outlay per household for food is registered with regard to various food types[19]. From these figures it is evident that the inhabitants of Oslo buy 2 per cent less meat, 9 per cent more fish and 12-15 per cent more fruit and vegetables than the national average. The spending in restaurants is, however, not

[18] In this case, figures are given for annual spending within the following consumption categories: food, beverages and tobacco, clothes and shoes, housing, electricity and fuel for heating, furniture and household articles, nursing, transport, private transport, public transport, post and telephone services, culture and leisure, hotel and restaurant services, other goods and services.

[19] 0111 Bread and cereal products, 0112 Meat, 0113 Fish, 0114 Milk, cheese and eggs, 0115 Oils and fat, 0116 Fruit, 0117 Vegetables, incl. potatoes, 0118 Sugar, chocolate, other sugar products, and 0119 Other foodstuffs.

differentiated according to the various food types. Nevertheless, in this case, we decided to use the differences in the figures for households' direct purchase of food. Based on the estimates shown below, we have seen that the consumption of arable land per person in Oslo, in relation to the overall consumption of food, is 8.2 per cent higher than the national average, while the figure for pasture land is 0.2 per cent lower than the national average.

Table 3 Direct land-use in relation to the consumption of various food types for Norway and Oslo. Figures from FoN (1996) adjusted with data from the Consumer Survey (2000)

Product	*Global yield (kg/ha)*	*Production (ton)*	*Import (ton)*	*Export (ton)*	*Net consumption (ton)*	*Footprint Norway, ha/cap*			*Difference Oslo*	*Footprint Oslo, ha/cap*		
						arable land	*pasture*	*sea*		*arable land*	*pasture*	*sea*
Fish	48				702 290			9.08	+9.1 %			9.90
Beef	24	86 000	4 807	43	90 764		0.88		-1.9 %		0.86	
Sheep and goats	52	27 000	256	18	27 238		0.12		-1.9 %		0.12	
Milk	336	1 926 300	651	156	1 926 795		1.31		1.1 %		1.33	
Cheese	34		2 584	22 549	-19 965		-0.13		+1.1 %		-0.14	
Butter	34		4	2 419	-2 415		-0.02		-2.3 %		-0.02	
Egg	550	51 000	408	475	50 933	0.02			+1.1 %	0.02		
Cereals	2 641	1 335 000	633 900	19 800	1 949 100	0.17			+9.1 %	0.18		
Fruit and veg.	12 120	283 000	215 721	254	498 467	0.01			+14.2 %	0.01		
Soybeans	2 115	-	324 940	10	324 930	0.04			-2.3 %	0.03		
Sum	-	-	-	-	-	0.24	2.16	9.08	-	0.25	2.15	9.90

Indirect energy consumption for *clothes and shoes* and consumption of arable and pasture land for clothes (cotton, leather and wool): The Consumer Survey shows that households in Oslo in 1998-2000 spent 14.5 per cent more money on clothes and shoes than the national average, while the difference for clothes was only 16.5 per cent.

Indirect energy consumption related to the consumption of *leisure goods and services*: We have selected the following categories from the Consumer Survey: "091 Audio-visual equipment", "092 Other goods, culture and leisure", "093 Other equipment, leisure and garden", and "094 Services, culture and leisure". Together, these give us a 7.9 per cent lower consumption for Oslo than the national average.

Consumption of *paper*: We have used the Consumer Survey here as well. For the category "Newspapers, books, and writing material", Oslo has a per capita consumption which is 15 per cent higher than the national average.

Indirect energy consumption related to the consumption of *furniture and other equipment*: here we presuppose a direct relationship between the total consumption of furniture and other equipment and the number of housing units. Consequently we have derived proxy data by adjusting the average figure for embodied energy (Farsund et al. 2001) by use of figures from the housing statistics which shows that the number of housing units in Oslo is 23 percent higher than the national average.

Embodied energy in housing: 90 per cent of the indirect energy consumption for housing is related to the actual construction of the housing (Farsund et al. 2001). Consequently, a direct relationship between the size of the housing unit and the consumption of energy during the construction process is assumed. As a result, we have derived proxy data for the embodied energy by using building-area statistics, which show that the total newly-built living area per capita in 1999 was 48 per cent lower in Oslo than the national average.

Consumption of *lumber* for housing: in this case we have assumed that the annual consumption of timber in the restoration, renovation, and building of new housing is related to the total living area of wooden housing in Oslo. Since 1983, municipal statistics on living area of houses have been kept for new buildings, grouped according to the type of housing. Prior to 1983, only statistics concerning the number of new housing were kept, so there are no municipal figures for the total living area for housing. As a consequence, we have derived proxy data based on the total number of housing units, and then made an estimate of the average living area for the various categories of housing. In absolute figures, this results in an estimate which is too high, because the average living area per person has increased in recent decades. We find that the living area per person in *wooden housing* is roughly 50 per cent lower in Oslo than the national average, while the total living area for all types of housing is only 5 per cent lower in Oslo. This reflects the fact that relatively little housing in Oslo is based on lumber, in comparison with the rest of the country.

Passenger-kilometres (passenger-km) for *private cars*: We have studied the county figures of the Road Traffic Authorities for the number of registered private cars per capita, which. is 11 per cent lower than the national average. We have multiplied this with county figures from 1997 for the average annual driving distance (Monserud 1997). The total passenger-km per capita for private cars represents a 17 per cent lower figure than the national average.

Passenger-km for *air transport*: There are no available statistics for county fluctuations in passenger-km in relation to air transport. However, travel studies have been carried out which provide county figures for frequency of flights, i.e. the number of journeys made annually on domestic and international fights, respectively, along standard routes (Rideng et. al. 1999). This shows 9 per cent fewer domestic flights, but as much as 127 per cent more international flights annually per capita in Oslo. For international charter tours, we have used figures from the Consumer Survey, which show 20 per cent higher spending per capita than the national average.

Conversion to Footprint

The next step in the calculations is the conversion of the consumption data to an *ecological footprint* measured in hectares (biologically productive land). To achieve this, we have used four major conversion factors (see table 4 below), mainly drawn from the “Footprint of Nations” (WWF 2001).

Table 4 Global conversion factors used in the Oslo footprint

Consumption	*Conversion factor*
Consumption energy land for the binding of carbon from the combustion of oil and gas	1,922 m^2/kg CO_2
Consumption of built land in relation to hydro-electric power from dams, dry rivers and power lines	0,0028 m^2/kWh
Consumption of forested land for the production of paper	4,405 m^2/kg
Consumption of forested land for the production of timber for housing construction	3,846 m^2/m^3

The final step in the footprint analysis is to adjust the value of the various land types, according to their biological productivity, so they all can be added to obtain a total footprint result (cf. table 5 under). It is worth noting that built land is assigned with the same equivalence factor as arable land. Built land has often originally been used for cultivation, as more or less was the case for Oslo. Further, the table shows that energy land, which is the land needed to absorb CO_2, has been assigned the same equivalence factor as forested land with other uses.

Table 5 Equivalence factors (WWF 2001)

Land types	*Equivalence factor*
Arable land	3.2
Pasture land	0.4
Forested land	1.8
Built land	3.2
Energy land	1.8
Bioproductive sea space	0.1

Finally, we add the footprint for the six main components of local consumption: local production, local waste treatment, food, goods, housing and transport, to obtain the ecological footprint per capita.

RESULTS

The ecological footprint of Oslo

Our analysis shows that each Oslo inhabitant has an ecological footprint of approximately *80,000 m²,* or the equivalent of *11 soccer fields*. In total, Oslo's population, by their consumption, exploit roughly *4,000,000 hectares* of biologically productive land, or 90 times the area of Oslo. The footprint becomes more meaningful if we compare it to the globally available biologically productive land, which in 1996 was calculated to be 2.18 ha per capita (WWF 1996). If the world's population had a similar consumption, we would need *three extra planets* to live on.

Table 6 The ecological footprint of Oslo 2000, in hectares per capita

	Land types[20]						
Local activities	*Energy land*	*Arable land*	*Pasture*	*Forest*	*Built land*	*Sea*	*Total*
Local production	0.261				0.022		0.283
Consumption of food	1.139	0.798	0.831		0.104	0.614	3.486
Consumption of goods	0.251	0.002	0.059	0.211			0.522
Housing related consumption	0.356			0.541	0.047		0.944
Consumption of transport	1.569				0.014		1.583
Local waste treatment	0.014				0.001		0.014
Sub total	**3.590**	**0.799**	**0.890**	**0.752**	**0.187**	**0.614**	**6.833**
Global responsibility for the protection of biological diversity (+ 12 per cent)							0.932
Total							**7.765**

In Table 7 we have shown the distribution in per cent between the local activities and various types of land area consumption. From this we can deduct the following general conclusions:

- *Household consumption* emerges as the dominant component, representing over 95 per cent of the total ecological footprint of Oslo.
- *Fossil energy resources* represent more than half of the ecological footprint.
- *Food* represents half of the ecological footprint.
- Consumption related to *housing* and *transport* represents nearly 40 per cent of the ecological footprint.

[20] Cf. discussion of land types on p. 14.

Table 7 Per cent distribution of the ecological footprint of Oslo in 2000 (global responsibility for preservation of biological diversity not included)

	Land types						
Local activities	*Energy*	*Arable land*	*Pasture*	*Forest*	*Built land*	*Sea*	*Total*
Local production	3.8 %				0.3 %		4.1 %
Consumption of food	16.7 %	11.7 %	12.2 %		1.5 %	9.0 %	51.0 %
Consumption of goods	3.7 %	< 0.1 %	0.9 %	3.1 %			7.6 %
Housing related consumption	5.2 %			7.9 %	0.7 %		13.8 %
Consumption of transport	23.0 %				0.2 %		23.2 %
Local waste treatment	0.2 %				< 0.1 %		0.2 %
Total	**52.6 %**	**11.7 %**	**13.0 %**	**11.0 %**	**2.7 %**	**9.0 %**	**100.0 %**

In Table 8 we have further presented the footprint per sub-component in order to study the result more closely. From this table, we can, in addition to our earlier conclusions, deduce the following:

- Emission of greenhouse gasses represents one third of the footprint for *food;* the remainder consists of direct land-use (arable land, pasture and sea space).
- In the *housing* component, roughly 40 per cent of the footprint results from the actual use of the housing (which encompasses the energy embodied in furniture/equipment and the direct consumption of energy). The rest of the footprint for housing is associated with the *construction* of the housing.
- In the *transport* component, *air transport* emissions are clearly dominant, and are responsible for over 60 per cent of the total contribution from transport.
- The footprint in relation to *waste treatment* has been reduced by roughly 50 per cent, due to various local initiatives aimed at recovering energy from waste.

The largest sub-component related to *housing* is the consumption of *lumber* (cf. Table 8). This reflects the fact that in Norway lumber is an important building material. It might be claimed that the consumption of lumber for housing does not represent a major environmental problem in Norway, as long as we have large areas of forest. Additionally, the forest growth rate in Norway at the moment exceeds the rate at which the timber is harvested. It may thereby be claimed that there should be an *increase* in the consumption of Norwegian lumber production from the point of view of ecological goals - the optimal exploitation of renewable resources (timber) will reduce the consumption of stored-resources (e.g. sand for concrete). However, the situation is not that straightforward, at least not in the context of the ecological footprint. Footprint analyses relate to resources as being *global* resources, e.g. by using global yield factors. The methodological approach has its strength by being able to show how large the *national or local* consumption is in relation to the *global* access to biologically productive land. Further, a lot of the lumber used for the construction of housing in Norway is imported. Norwegian forestry has also an environmental cost associated with the loss of *biological diversity*. So, although a case might be made for an increased use of timber resources in Norway on the basis of consideration for national resources, this is a problematic strategy with respect to the environment. Consequently, it seems highly relevant that the heavy consumption of lumber is being highlighted in a footprint analysis.

Table 8 Per cent distribution of the ecological footprint of Oslo in 2000, per sub-component (global responsibility for preservation of biological diversity not included)

Theme/categories	*Share of total footprint*
Local production	
Emission of greenhouse gasses, private and public sector	4 %
Direct land-use, private and public sector	<1 %
Energy consumption - electricity	<1 %
Household consumption	
Food:	
Indirect energy consumption (production, transport)	9 %
Methane from farm animals	3 %
Nitrous oxide from fertiliser	4 %
Arable land	12 %
Pasture land	12 %
Built land (farm buildings etc.)	1 %
Bioproductive sea space	9 %
Goods:	
Clothes and shoes	3 %
Leisure goods and services	2 %
Paper	3 %
Housing:	
Direct land-use for housing	1 %
Furniture (i.e. embodied energy in furniture and equipment)	2 %
Materials (i.e. embodied energy in housing units)	1 %
Timber	8 %
Energy consumption - electricity	<1 %
Energy consumption - oil	4 %
Energy consumption – fire wood	<1 %
Transport:	
Direct land-use for transport	<1 %
Emissions from private cars and taxis	8 %
Emission/el-consumption from boat, bus, train, tram, subway	<1 %
Emissions from air transport	14 %
Local waste treatment	
Direct land-use (waste and sewage purification plants)	<1 %
Direct energy consumption (waste and sewage purification plants)	<1 %
Emission of greenhouse gasses from landfills	1 %
Energy production (methane-> CO2, saved oil and el-consumption)	-1 %

The large footprint related to *air transport* reflects two conditions: the consumption of air transport per capita is much higher in Oslo than the national average, and the ecological footprint for completed passenger-kilometres is larger for air transport than for other types of transport.

Although we have not managed to include all types of recycling efforts in the footprint analysis, our analysis illustrates the great gain to be made regarding the reduction of the waste footprint concerns the reduction of the *volume* of waste (or rather consumption), not how the waste is treated.

The consumption of food in Oslo

Of all the consumption components, the consumption of food represents by far the largest contribution to the ecological footprint of Oslo - about half of the footprint. Consequently, the food component should be regarded an important area within the field of consumption and environmental concern. The report from the Dutch “Perspective Project” concludes that it is easier to change people’s habits concerning the consumption of food in a more environmentally-friendly direction, than it is for the two other components; housing and transport (The Dutch Energy Agency)[21]. Consequently, emphasis on the consumption of food appears to be *of special* relevance.

With respect to the consumption of food, there are four strategies that seem to be relevant for local initiatives:

- More local food; locally grown food that is sold and consumed near to the point of production to reduce transport.
- More wild fish and vegetables; less consumption of food which creates a large ecological footprint, such as dark meat and farmed salmon.
- Increased consumption of eco-labelled food whenever possible.
- Reduction in wasted food (home-composting is not as effective).

Worth mentioning is also that the energy consumption for transport between *grocery store and household* has increased for the last thirty years, and that this today represents a major part of the energy consumed for transport of food from the field to the table (Brendehaug 2001). A reason for this is that people use their car for shopping more than before, the distance to the stores have increased, and the customers do not always choose the nearest shop. This should be taken into consideration in planning efforts to reduce the food footprint.

Different foodstuffs consume various types and amounts of land and some are more energy-rich than others. Various *changes in diet* can be most beneficial in relation to reducing the ecological footprint. For instance, the production of fruit and vegetables is 500 times more land-effective than beef production (measured in kg/hectares). With respect to energy consumption, the picture is somewhat different. The transition from beef to mutton for example, would involve a potential reduction of up to 50 per cent in the ecological footprint, while a change from beef to cereal products would involve a reduction of up to 95 per cent.

However, the substitution of fish for meat is not necessarily synonymous with a reduction in the footprint. A transition from sheep to farmed fish could, for instance, involve an *increase* in the footprint of about 50 per cent. The footprint per energy unit (ha/kcal) of farmed fish may be twice as great as that of wild fish (Aall and Norland 2002).

[21] In this project, a group of families received an annual financial grant and supervision from a research team. The project lasted for three years. The basic intention was to determine if the families could combine economic growth with reduced impact on the environment. The investigations that were carried out at the end of the project showed that this was possible; the families travelled less, which reduced their energy consumption; and they changed their diet to a more environmentally-friendly one. However, it became apparent that the situation had changed when the researchers observed the families one year *after* the experiment was concluded. The families had taken an extra holiday trip they had not “dared” to take while the project was underway. A change which did, however, last was that made in their diet.

The transition from a conventional to an *eco-diet* can also involve an environmental gain. Analyses suggest a gain on the order of a 10 per cent reduction of the total footprint from food. The reduction is due first and foremost to the fact that ecologically-cultivated food involves a reduced use of fertilisers, and a lower emission of nitrous oxide due to better earth structure[22]. The difference may also be due to less energy consumption in production, but this is more uncertain since explicit demands are not made for energy consumption or transport in ecological farming.

Reducing *food wastage* can be proposed as a fourth strategy for reducing the footprint of consumption of food. Composting of food can also be a sensible measure for reducing local pollution problems, but it will not lead to a major reduction in the ecological footprint, since the product (compost), can, in practice, replace other consumption goods only to a limited extent. If food waste were to be used as animal fodder, however, the footprint would be reduced. The largest positive gain, however, would be achieved by consuming less food; for example by using food more efficiently and reducing waste from both large-scale operations and private households. Analyses have shown that we waste as much as one quarter of all the food we buy (Aall and Norland 2002).

The consumption of housing in Oslo[23]

With respect to housing and *housing-related consumption*, one key condition emerges as being particularly significant. The housing-related consumption is determined largely by the size of the *living area*. This is partly due to the house's original base area. Secondly, a larger living area will normally result in a higher consumption of energy for heating, as well as a higher consumption of furniture and other household items. Thirdly, the size of the living area determines the consumption of lumber needed for construction and maintenance of the house.

Energy analyses have shown that the operation of a housing-unit represents as much as 90 per cent of the total impact on the environment. Interestingly, our footprint analysis identifies this relation to be roughly 40:60, with the difference primarily due to the consumption of lumber used in construction. The footprint analysis highlights an important point; that a large living area is *in itself* an expression of a high consumption of resources, *as well as* an indication of high consumption due to the operation of the housing unit. Land-use planning and other forms of regulation which involve smaller living areas per capita will consequently result in a long-term effect in the form of reduced consumption of resources in both the construction and operation of housing units. In 2000, the average size of new housing units in Oslo was 123 m^2 compared to the national average of 144 m^2. The consumption of living area in Norway has increased by 43 per cent in the last 20 years, and the average living area per capita is roughly 25 per cent larger in Norway than in other industrialised countries (Bramslev 2000).

More detailed footprint analyses (Holden 2001) show that housing density, distance from the city centre, and the type of housing determine the total footprints of the separate households. Such analyses provide a basis for discussing the various models for sustainable towns. On one hand, there are those who propose that relatively dense housing patterns, with a low percentage of detached houses, result in a lower per capita consumption. Such

[22] Another, and at least equally important, advantage which is *not* considered in footprint analyses is the reduced use of insecticides.

compact towns, it is claimed, not only satisfy the principles for energy-saving planning, but also generally meet the demands of sustainable development. On the other hand, there are those who propose a relatively open town structure, or *green towns,* involving the development principle of a potential reduction in the circulation of local resources. Our calculations suggest there is a basis for promoting a *decentralised concentration* as a profitable compromise between the two models. Such an approach involves support for establishing compact *"mini-towns"*; in this context, within the borders of Greater Oslo. Such "mini-towns" would be characterised by:

- High utilisation of land so that public and private services are within the range of pedestrians and cyclists.
- Mixed land-use, so that offices, shops, business and trade activities and public and private services are integrated into the housing area.
- Limited traffic and parking areas with a strong emphasis on ensuring a pedestrian and bicycle net.
- Central nodes for public transport (rail, subway or bus stations), and well-developed public transport connections for commuting.
- Proximity to public services such as schools, libraries, welfare centres and nurseries etc.
- A high degree of local self-sufficiency in order to meet daily needs.
- Public open spaces with a strong emphasis on design (fountains, street furniture, street courtyards etc.).

It might be added that this is already an integral part of Oslo's planning and development. It should be of interest, however, that the analysis within the Oslo Project confirms the environmental advantages of such a strategy.

The consumption of transport in Oslo

The footprint analysis reveals that the transport of people by air clearly dominates the transport component of the Oslo residents' footprint, rather than transport by private car. Although private car passenger-kilometres is greater, *air transport* still represents the largest contribution to the total footprint. The emission of carbon dioxide from the three types of air transport (domestic flights, international flights and international charter tours) is, if all factors are considered, totally dominant. This follows from the assumption that the emission of water vapour and NO_x from aircraft flying at high altitudes contributes to a substantial greenhouse effect which is not reflected in normal calculations for greenhouse gasses. We also note that the total direct land-use (for roads, runways, airports, fuelling facilities etc.) is secondary to the footprint associated with the use of fuel.

Our analysis reveals that the inhabitants of Oslo take 9 per cent fewer domestic flights, while they travel abroad twice as often as the average Norwegian. International flights dominate the footprint. International flights, excluding charter tours, produce a footprint almost 20 per cent greater than private car transport. Business travellers on both domestic and international flights constitute around 60 per cent of the total passengers (Rideng and Denstadli 1999). International and Norwegian studies, however, indicate that non-charter

[23] The text in this sub-chapter is partly based on Holden (2002).

recreational flights are on the rise. Phenomena such as “City Weekends”, “Fly and Drive” and “Shopping Expeditions” by air, and combined business-and-pleasure journeys, have contributed to this trend (Rideng and Denstadli 1999).

Although the footprint associated with private car use is less dominant than the air transport footprint, private cars still contribute heavily to the total footprint. Two changes in particular are essential to the reduction of the footprint associated with private car use: less travel in general, and the replacement of private-car use with public transport.

In summary, with respect to *transport*, the following measures are central:

- Reduction in the amount of air transport abroad: Oslo has a much higher consumption of air transport than the national average. Increased use of video-conferences and choice of holiday destinations that do not involve air transport should be encouraged.

- Reduction in private car ownership: Oslo has a relatively low per capita figure compared to the national average.

- Reduction in leisure driving: The advantage of low per capita car ownership is partly negated by the high level of leisure driving.

- A strengthening of public transport, which could be combined with restrictions on private car use to enhance the effectiveness of the measure.

A fifth strategy *might* also contribute to the reduction of the ecological footprint of private car use: the gradual replacement of petrol and diesel with alternative fuels. We know from various studies that the advantages with respect to local air pollution, and sometimes greenhouse gasses and total energy consumption, for a given amount of passenger-kilometres, can be considerable[24]. Studies, however, indicate that the *land* requirements for some alternative energy sources might be problematic (Høyer and Heiberg 1993). Rough estimations indicate that certain alternative energy sources can produce a bigger ecological footprint than conventional petrol-driven cars (see Table 9).

Table 9 Estimate of land-use per unit passenger-kilometres for different energy sources. Figures in m^2 per passenger-kilometre (based on Høyer and Heiberg 1993)

Fuel	*Direct and indirect land area use*	*Energy land*	*Total*	*Improvement-potential*
Methanol	0.49	0.12	0.61	56 %
Natural gas CNG	n.a	0.41	0.41	7 %
Electricity (hydrogen)	0.02	0.36	0.38	-2 %
Hydrogen (LH_2)	n..a.	0.11	0.11	-72 %
Hydroelectricity	0.01	0.04	0.05	-86 %

Oslo - a city in Norway

Previously, we compared the footprint of Oslo with the global availability of biologically productive land. Another equally interesting comparison would be the footprint’s relationship to the average *national and global consumption* of such land. Due to different methodological

[24] See the database on alternative fuels compiled by Western Norway Research Institute in cooperation with the Technological Institute: http://www.teknologisk.no/drivstoff/.

approaches and data sources, a direct comparison is not easily made. The major differences between our methodology and that used in other national and global footprint analyses are:

- We have included figures for indirect energy consumption for food.
- We have reduced the number of sub-components, from 175 in FoN to 27.

Only by calculating the national footprint of Norway in the same manner and with the same data as the Oslo footprint we might obtain comparable figures. The footprint of Oslo would then be roughly *17 per cent lower* than the national average, although the inhabitants of Oslo have a higher consumption than the national average with respect to several key components:

- The footprint for *air transport* is 60 per cent higher
- The footprint for *food* is 5 per cent higher

However, three areas in which the ecological footprint per capita is considerably *smaller* in Oslo than the national average more than compensate for these higher figures:

- Oslo is a "de-industrialised" city with a 74 per cent lower footprint for emissions of greenhouse gasses from industry.
- Oslo uses 47 per cent less lumber for housing than the national average.
- Oslo has a lower level of car ownership, which gives it a 17 per cent lower footprint with respect to private car use.

In addition, we have also observed considerably lower footprints of less critical components, such as lower per capita living area, use of fire wood and emissions associated with bus transport.

If we consider only *household consumption*, and do not include the footprints of local production and local waste treatment, the difference between the national average and Oslo is reduced to a margin of only *1 per cent lower* for *Oslo.* In other words, the gains Oslo has from a lower per capita living area (lower consumption of lumber and embodied energy in housing) and lower private car ownership (lower consumption of private car transport) is largely compensated by a considerably higher consumption of air transport, as well as food.

Is it possible to say anything about how our Oslo footprint compare to the global and national footprint analyses which are done internationally? The figures for Norway within "Footprint of Nations" (FoN) give a footprint of *6.14 hectares* per capita, if we exempt land required for the preservation of biological diversity (WWF 2001). Our footprint is thereby 30 per cent *higher* than the figures published in FoN. One might have expected our figures to be *lower* since we have limited the number of components for which we have generated a footprint. To achieve a reasonable comparison, however, our figures must be adjusted to make them more comparable to those in FoN. First of all, we must delete the emission of *greenhouse gasses* associated with *food* production from our analysis, since this is not included in FoN (minus 1.09 hectares per person). We must also ignore *local production* (1.09 hectares) and *local waste treatment* (0.34 hectares). The modified footprint of Norway, according to our approach, would then be *5.71 hectares per person*, which is 7 per cent *lower* than the FoN figure.

Even with the corrections shown above, our figures seem rather high in relation to the FoN figure. Since we have made a selection of components (emphasising the three main components: food, transport and housing), we might have expected a greater difference than the 7 per cent shown in the table below. Nevertheless, it appears that our methodological approach agrees well enough with the FoN figures that a comparison between our calculations and the FoN calculations of the *global average* for the ecological footprint per person seems meaningful. A comparable adjustment of the footprint for Oslo (as done for Norway above) with the reduction for greenhouse gas emissions associated with food (1.14 hectares), local production (0.28 hectares) and local waste treatment (0.01 hectares) - gives an *adjusted footprint for Oslo of 5.38 hectares per person*. In 1996, the global average footprint was calculated to be 2.18 hectares per person (WWF 2001). The table below shows that *a resident in Oslo has, on average, an ecological footprint which is nearly 3 times the global average.*

HOW TO USE THE FOOTPRINT ANALYSIS

Are ecological footprints suitable as local analytical tools?

The observations made in the previous chapter require us to address the basic question *whether the ecological footprint is a suitable tool for analysing local variations*. By “local” we mean sub-national administrative units such as municipalities and counties (regions). In other words, is the ecological footprint a tool which can be employed in municipal environmental policy? Discussions so far suggest that the answer is “maybe”. Showing variations between local communities in *different countries* appears particularly difficult. If one is to make international comparisons, a standardised methodology is required, and then *national* averages would have to be used to a greater extent, which only to a limited degree could be adjusted to reflect local conditions.

It is easier to show variations *within* a country. In this case, at least, one has better control over factors such as methodological approach and equal access to data; but the size of the discrepancy will still be an open question. We have determined a difference of 17 per cent between the footprint of Oslo and the national average. We have yet not carried out analyses for other Norwegian municipalities. Access to local consumption data and other local data which can be compared with the national average is probably better in Oslo than in other Norwegian municipalities. In other municipalities, especially the smaller ones, we would probably be forced to use unadjusted national consumption data, and would therefore be unable to discern local variations from the national average. Without these variations, the footprint seems less suitable for comparing different local communities.

On the *personal level*, variations appear to be large; Data from Oslo provides examples of variations approaching a factor of 100:1 (Holden 2001). It will therefore be necessary to supplement the municipal footprint analysis by designing an individual-footprint calculator which will allow the calculation of individual footprints. The result could, for example, be reported on three different scales: as greenhouse gas emissions, energy consumption and as an ecological footprint[25]. In this way, one could demonstrate that various climate initiatives can have side effects. For instance, in converting from oil to fire wood for heating, one reduces the emission of greenhouse gasses, but increases the ecological footprint.

Although the footprint may turn out to be inadequate as a tool for comparing municipalities internationally and nationally, it might still be of interest *within* a given municipality. We would then retain three major areas of applicability:

– Internal comparisons *over time* for the municipality as a whole
– More specific sector evaluations
– Individual calculations

The data sources we have used and the methodological approach that we have developed make it possible to carry out assessments within these areas.

[25] See http://www.vestforsk.no/miljo/klimakalkulator/

Areas of applicability

In general, indicators may be applicable in a variety of contexts. They can be used to predict future developmental trends, to provide a clearer picture of changing conditions or perhaps to map the effects of initiatives and actions. Normally, this will involve the following types of *analyses* (Høyer and Aall 2002):

- Indicators for the clarification of developmental trends ("trend analysis").
- Indicators for *comparing* one's own performance with other municipalities nationally and internationally ("benchmarking").
- Indicators for reporting upwards in a decision-making hierarchy ("reporting")
- Indicators for clarifying the *impacts* of planned initiatives and actions ("impact assessment")
- Indicators for registering and *evaluating the effects* of executed initiatives and actions ("evaluation")
- Indicators for registering and monitoring the *development of a condition*; for example the state of the environment ("environmental control")

The various analyses will normally be aimed at different target groups, and may also require different types of data or degrees of precision in the information represented by the indicators. We will return to this matter later.

Another important difference concerns the question of the *governing* contexts in which the indicators should be involved, that is, if they are (Høyer and Aall 2002):

- Indicators for public *information and debate*, i.e. attitude-forming efforts aimed at various local actors.
- Indicators for *political* guidance; i.e. with the elected representatives as the main target group and used when decisive and principle-based political decisions are taken.
- Indicators for *administrative* guidance, i.e. when primarily the administration is involved in evaluating the impact of various development alternatives, but where the elected representatives are brought in to sanction the actions of the administration or to make subsidiary and more detailed political decisions.

The combination of the dimensions "type of analysis" and "governmental contexts" provides a series of various fields of application. The point here is to emphasise that the ecological footprint probably is not applicable in all possible contexts. The characteristics of the ecological footprint as a tool will determine the contexts where its use might be justified. The most important aspects which should be considered are, in our opinion:

- The *type of information* which is to be imparted: it is particularly important to be aware of the kinds of information the ecological footprint does *not* convey. In this case, the question of local pollution and the use of chemicals are important cues. Also, it is obviously important that one recognises what kinds of information the ecological footprint actually does convey. Important key phrases are: focusing on consumption as opposed to production; identifying both direct and indirect consumption; relating our consumption to global resources and shared limitations; and relating biological diversity to the measurement of our exploitation of biologically productive land.
- The *intelligibility* of the information which is to be imparted: although the concept of the ecological footprint seems to be intuitively understandable, complicated reasoning and some speculative assumptions are baked into the method. It is especially challenging to explain to the general public the premises on which the footprint analysis is based, and what kind of information the footprint actually imparts.
- *User-friendliness* for those who will carry out the actual analysis: here the critical conditions are associated with access to local data and the perceived complexity of the required calculations.

- *Information value*: in the context of sustainability, it is especially important to determine the degree to which the ecological footprint is able to indicate *change*; i.e. if and to what degree the footprint will change in response to variations in consumption.

From the considerations mentioned above, we believe that the ecological footprint can be applied to a variety of contexts with respect to municipal environmental policy - given the methodological approach we have chosen with its emphasis on using genuine local data as far as possible. We believe that the ecological footprint can be applied to all three administrative contexts we have mentioned above, but that the footprint methodology must be used differently for each administrative context.

Table 11 Areas of applicability for the ecological footprint

Administrative context	*Type of analysis*	*Practical application*
Information and debate	– Individual/household evaluation	– In education – As an element of environmental protection work – Publication on the municipal home page
Political management	– National benchmarking – Trend analysis	– In annual reports – In municipal planning reports
Administrative planning	– Impact assessment	Incorporation in existing systems of impact assessment in administrative procedure.

Information and debate

We suggest that the municipality of Oslo should add a link to an existing "climate calculator"[26] on, for example their home page www.oslo.kommune.no; symbolised with a logo. Simply making such a tool available will probably not be particularly effective. Experience indicates that it is important to associate such tools with specific social contexts. In the case of Oslo, it might be desirable to associate the tool with education and any general attitude-forming work in which the municipality is involved.

A calculator for individual footprint calculations could be introduced to the educational system, and be integrated in a number of subjects, such as "Resources and Consumption", "Biological Diversity" and "Climate Studies". There seem to be few teaching aids and tips which are specifically designed for these themes.

In connection with Local Agenda 21, Oslo has begun to work alongside the non-governmental organisation "The Environmental Home Guard" (*Miljøheimevernet i Oslo*). This organisation encourages the "greening" of households, and could pave the way for the use of the calculator in their study program for families. This could be done by using the calculator to work out a score for each household before and after participating in the study program, in order to measure how effective the program has been.

A more advanced used of the "climate calculator" might be to create a *footprint bank*, in which those who use the calculator can anonymously register their response (their footprint profile)[27]. This would enable them to evaluate their own progress over time, as well as to compare their scores with others. If the users also agree to enter background information

[26] See http://www.vestforsk.no/miljo/klimakalkulator/.
[27] As being done within *De Kleine Aarde*'s footprint campaign (www.dekleineaarde.nl)

about themselves such as income and educational level, anonymously, and if permission is granted by the Data Inspectorate, the data can then also be used in a variety of other analyses conducted by the local authorities. For example, one might investigate what groups participate in such efforts, and if the efforts success is dependent upon income or educational level.

Political management

The analysis which is presented in this report is primarily intended for use in association with the more general and strategic evaluations in the municipal environmental policy, of the type “where are we headed?” and “what will be our future goals in environmental protection”? The analysis might, for example, provide a basis for considering “food consumption” in municipal environmental policy. The analysis would also illustrate that although the municipality has only a limited ability to influence consumption in favour of sustainable development, it can nevertheless make important contributions to environmental policy, also with respect to global and development problems. In other contexts, we have termed such general guidelines *trend analysis* (Høyer and Aall 1997, Aall 1998).

The term “trend analysis” is based on the concept of using strategic assessments of society’s developmental trend in relation to achieving the objective of sustainable development. Trend analysis is associated with systems for strategic impact assessment, a preventive environmental strategy and attempt to translate into concrete terms the use of a ”precautionary principle” policy in municipal planning (KS 1993). Ecological footprints offer a way to express environmental impacts in mathematical terms which facilitates their use in a program of trend analysis. Situations in which this type of evaluation can be made are:

- Annual reports
- Municipal planning
- Environmental impact assessment of major plans and programs

There are two important preconditions associated with this use of the ecological footprint. First of all, as already mentioned, it is important to know what is *not* included in ecological footprint analyses. This is not an indicator which is applicable to all environmental problems. It must also be assumed that, as with any form of indicator-based management, there exist some form of *environmental goals* for which one can compare results. In principal, one could simply have the general goal of reducing the ecological footprint, perhaps expressed as a per cent of the original value. In keeping with the first precondition, however, it is equally important that one has clear ecological goals *beyond* the simple aim of reducing the ecological footprint. This is due to possible conflicts between the footprint and other legitimate environmental policy goals; for example the goal of reducing local air pollution. This goal would not be considered in an ecological footprint analysis.

Administrative planning

Ecological footprint analyses may also be of value in more limited administrative evaluations associated with the administration of various projects and building alternatives. As demonstrated in the discussion of housing related footprints, this type of analysis can identify the impacts of various *building construction alternatives*. The footprint can be used to evaluate various tenders/alternatives in development processes, for example where there are specific requirements for energy efficiency, land-use management and essential infrastructure. Both the construction process itself and the subsequent use of the housing would thereby be subject to a form of environmental management. Footprint approaches should in this case be specifically adapted and formally integrated into existing administrative routines. Footprints also are suitable for demonstrating that the use of alternative energy sources (such as replacing petrol-driven vehicles with battery-driven vehicles) may also have environmental impacts. Footprints may also be used in connection with conflicts involving biological diversity, since footprints reflect the use of biologically productive land and the impact of consumption. If such evaluations are to be used, *routines* and formal procedures should probably be established, specifying the *circumstances* (types of initiatives) where footprint analysis will be required, *when* it must be carried out, *who* must make the analysis and perhaps *how* the analysis should be carried out.

Changing environmental policy goals

We have already pointed out that ecological footprint analysis must not be done instead of, but *in addition to* the evaluation and assessment methods used within the municipal environmental policy. Our contention is that the use of the ecological footprint as an indicator or means of analysis brings *new perspectives* to the environmental debate. The ecological footprint illustrates the importance of addressing the environmental impact of *consumption* as well as production. It also introduces *new themes* into environmental policy (such as food), and helps to *reinforce* the focus on those themes that are already a part of the environmental policy agenda (such as transport, especially air transport). With respect to the traditional areas of interest in Norwegian municipalities, such as: water; sewage and waste collection; green structures; local air pollution; outdoors recreation and other forms of local environmental problems and challenges, it seems apparent that the ecological footprint can help to *extend* the environmental policy agenda. Perhaps it's most important contribution will be its ability to relate local environmental topics to global ecological issues in two ways: the global *environmental* problems are made local by relating the global use of biologically productive land to local consumption. In addition, local consumption is related to the question of fair *distribution* of material benefits on a global basis, by relating the local footprint to the concept of a universal quota for land use.

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