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Annex 1: Ecological Footprint Analysis

This Annex contains two short background papers:

- More about Ecological Footprint Analysis
- Critiques of Ecological Footprint Analysis

Paper 1: More about Ecological Footprint Analysis

What is an Ecological Footprint?

Footprinting essentially accounts the use of the planet's renewable resources (its 'interest' rather than its 'capital'). Non-renewable resources are accounted for only by their impact on, or use of, renewable, bioproductive capacity.

The footprint deals only with demands placed on the environment. It does not attempt to include the social or economic dimensions of sustainability.

The footprint is a 'snapshot' estimate of biocapacity demand and supply usually based on data from a single year. Both available biocapacity and the eco-efficiency of the economy can change over time which is why it is not possible to forecast or 'backcast' footprints from current data although it is possible to make assumptions about future consumption and thus create informative, but speculative, scenarios.

The use of bioproductive area as an aggregate unit makes it a powerful and resonant means of measuring and communicating environmental impact and sustainability. In this sense it is comparable to many economic indicators such as the Retail Prices Index (RPI) and GDP.

The Bathroom Scales and Footprints
The footprint has been compared to measuring ones own weight. You can find out how heavy you are, and the difference from your ideal weight, but the process of measuring does not tell you how to lose weight. However, you can speculate that if you do certain exercises and eliminate certain calorific foods from your diet you will shed a certain number of kilos.

An Additive Model

The basic ecological footprint is an additive model. It sums several mutually exclusive uses of bioproductive area; arable, forest (for both wood products and carbon sequestration), pasture, degraded or built land, and sea space.   Exceptions to the additive model have been made for footprinting certain types of pollution and water catchment where spatial uses overlap.

A key issue in the calculation of ecological footprints and biocapacities is the method used to aggregate areas of different quality facilitating international comparisons. Areas of generally different productivity (arable, pasture, forest, sea) are 'normalised' by multiplying them by equivalence factors relating to their bioproductivity. The equivalent areas are then expressed as standardised hectares of world average productivity (more recently referred to merely as 'area units').

Use of fossil fuel-derived energy is typically accounted for in terms of its carbon dioxide emissions although it is also possible to assess ecological footprints of energy use in terms of the land area required to sustainably derive biofuel alternatives. The former results in a more conservative estimate of the impact of fossil fuel use and have thus been the more common method.

Biocapacity

For calculation of national/regional biocapacity, local yield factors are introduced. These factors show how much higher or lower the yield per local ha is compared to the yield per area unit. There is always the possibility of converting ha of unit area into ha of national/regional average productive space for both supply and demand. Thus it is possible to answer two questions; *How many planets would it take to if everyone consumed as much as the average resident of Region X* and *How many Region X's would it take to satisfy the current demands of that Region*. This calculation was performed for the Isle of Wight (Chambers et al 2000). Using local yield values it was shown that two additional Islands would be needed to sustainable support consumption. Using global yield factors it was shown that, if everyone lived like the average Islander, 1½ extra planets would be required. The approach of using local yields is also favoured by a number of the studies reviewed in this report.

Some biocapacity must be set aside for non-human use. The necessary amount of pristine habitat is not known but, as a general rule in footprint calculations, not more than 88% of the existing biocapacity is considered 'available' for human use. The LPR 2000 accounts for biodiversity as a percentage of the footprint (demand). Previously biodiversity area has been subtracted from the available regional supply.

Paper 2: Critiques of the Ecological Footprint

Critical Studies

Several critiques of the ecological footprint exist (notably VROM-Council 1999, Van Kooten and Bulte 2000, van den Bergh and Verbruggen 1999, Pearce 2000). These reviews contain a mix of positive and negative comments relating to the application of the methodology as well as suggestions for improving its structure and use.

It is important to address these briefly both to understand the limitations of the methodology, its strength and weaknesses, and to assist in assessing the various applications of the methodology within the EU.

Answering the Critics

Here we paraphrase 10 key points listed by Van Kooten and Bulte (2000) and use these as a framework for comment. Their comprehensive critique is arguably the most harsh of those listed above and was used by Pearce as the basis for his submission to the EU Commission DGXI. One of the co-founders of the ecological footprint concept, Dr. Mathis Wackernagel, has also had the opportunity to address the points raised in a corresponding submission to the EU Commission (Wackernagel 2000) and here we draw on his comments augmenting these with our own thoughts and experiences. The reader is also referred to Chapter 6 of 'Sharing Nature's Interest' (Chambers, Simmons and Wackernagel 2000) which addressed these and additional points.

1. Footprint accounts are incomplete
Ecological Footprint Analysis does not claim to account for all human impacts on the environment. Instead it prefers to offer a conservative underestimate whilst acknowledging that other impacts exist. Most obviously, the accounts focus on resource consumption, with the exception of water, and underestimate the impacts of waste products.

However, several footprint studies have addressed both of these shortfalls. Chambers et al (2000) demonstrate two methods of incorporating water consumption into footprint accounts. The same publication presents a study which includes footprint estimates for several pollutants.

Other studies have tackled the complex task of accounting for pollutants other than carbon dioxide, for example, Folke et al 1997, Wackernagel et al 1997 though they remain excluded from National footprint calculations. The main hurdle to further integration of pollution accounting would seem to be a lack of reliable research data on the way in which pollutants interact and affect bioproductivity. Further discussion on this issue is contained within a paper by Holmberg, Lundqvist, Robért and Wackernagel (1999).

There is also some confusion amongst critics of the method as to what the footprint is intended to account. The footprint typically accounts only those resources which are part of the biosphere’s cycles. It is implicitly assumed that the use of heavy metals and hazardous chemical (those which are persistent, bio-accumulative or toxic) should either be eliminated or must be handled in totally closed loops which do not involve release into the natural environment. Studies have shown that the impact on bioproductive capacity of, for example, heavy metals are massive and usually swamp other effects of consumption. The natural assimilation rate of Copper, for example, is 42mg per square metre per year . The footprint of a kilogram of copper would therefore be 2.38 ha-years. The footprint of a kilogram of PCB's is an impressive 2,000 ha-years (Krotscheck & Narodoslawsky 1996).

2. Applying Carrying Capacity concepts to human populations is flawed. Evidence has shown that (a) humans, unlike other animals, can and do increase the carrying capacity of their environment to meet their needs and (b) certain regions and communities seem to be living beyond their local carrying capacity now with few ill effects.

Criticism (a) is based on a misunderstanding of how footprinting accounts for changes in biocapacity. As the footprint is a 'snap shot' measure, reflecting the supply and demand at the time of the analysis, future effects (such as increases or decrease in biocapacity) would only become apparent in subsequent analyses.

Criticism (b) ignores the fact that populations can exceed local carrying capacity either temporarily, by running down natural capital, or more permanently, by importing or appropriating capacity from elsewhere. Take the example of a fishing community dependent on a local lake for their food. They can over-fish the lake, temporarily increasing supply, by catching smaller and smaller fish. This will impact on the ability of the fish population to sustain itself leading to decline in stocks. This is of course what has happened on a wider scale in European waters where arguments have raged over the gauge of fishing nets which will allow the immature females to escape. Another option for the fishing community is to simply import produce from elsewhere, either fish or another protein substitute, thus appropriating carrying capacity form elsewhere.

3. The very process of aggregating land types to calculate a footprint assumes substitution - yet this is not possible.
This is a complex point raised in different forms by various commentators. Basically, this comment is based on a misunderstanding about the nature of the footprint as a measure of impact based on current biocapacity calculations. Aggregating information into a single indicator need NOT imply that the elements being measured are interchangeable in any real sense. For example, MTOEs (Million Tonnes of Oil Equivalent) is a common unit used for aggregating the energy content of different fuel types to derive a overall indication of energy consumption. Aggregating in this way does not imply that the fuels are in any way interchangeable - natural gas cannot substitute for diesel, for example.

4. Carrying capacity is irrelevant since resource yields can be increased in the case of renewable resources, and depletion profiles can be extended by technology in the case of non-renewable resources.

Indeed, carrying capacity can be altered: both eroded as in the case of desertification, and enhanced as in the case of careful management schemes. That's why ecological footprints are always compared to the biocapacity of a given year (as mentioned earlier). In fact, as footprint accounts point out, technological efficiency is one possible strategy to reduce humanity's draw on nature (as long as the efficiency gains are not outpaced by an increase in consumption).

5. Carrying capacity calculations have limited relevance when trade is possible since the scarce resource can be imported in exchange for another asset in which the exporting nation has a comparative advantage.

Footprint accounts do not argue against trade. They point out that not all countries can be net-importers of ecological capacity if global overshoot is to be avoided. Footprint accounts make ecological trade imbalance visible and show to what extent nations depend on net imports of ecological services. Further, Pearce's interpretation that shifting to imports from high-yield areas will reduce a country's overall footprint is incorrect. From a global perspective, this is a zero-sum game at best. And in fact, in our accounts, a shift to imports from higher-yield areas does not reduce the importer's footprint.

6. Certain economies that are highly urbanized (Netherlands, Singapore, Hong Kong) can never be sustainable since they can never meet their ecological demands from their own land.

Of course, urbanised economies are more likely, by definition, to need to import resources to meet their needs. This does not mean they can never achieve sustainability, it just means that they will have a more dispersed footprint which will have a certain transportation 'overhead'.

7. Footprinting is a survivability concept not a sustainability concept. Survivability is about maximizing the time available on Earth for human species, independently of the quality of that existence.

Certainly footprint estimates are a *minimum* requirement for sustainability. In other words, living within global carrying capacity is necessary but not sufficient for sustainability. It may be desirable to increase the footprint to allow for a higher quality of existence.

8. Calculating the fossil fuel footprints in terms of area needed to absorb the corresponding CO_2 is inadequate according to some critics.

The area included for CO2 sequestration represents the degree by which the planet would need to be larger in order to cope with anthropogenic CO_2 output. Finding other ways to combat atmospheric CO_2 accumulation would open dramatic possibilities for reducing humanity's footprint. Calculations for various forms of renewable energy are included in Chambers et al (2000).

Another method of calculating the fossil fuel footprint is to assess the biological area necessary to produce a substitute. This would lead to even larger footprints.

9. There are substantial uncertainties about how to calculate the land areas required to offset waste flows.

The science of accounting for various pollutants is in its early stages and by omitting these footprint studies underestimate environmental impact. Examples of studies where the footprints of wastes have been included are referred to earlier.

10. Footprint accounts make no distinction between land uses that are sustainable and those that are not.
This is correct. But as mentioned previously changes in productivity due to unsustainable land use do appear in future estimates of biocapacity. If activities in one year lead to an increase in desertification, for example, then the bioproductive supply will decrease in subsequent years.

Annex 2: Summary of current EF applications in Europe

1) Global Footprints: A pilot project with 8 municipalities in the Netherlands 1999-2001

Project management: 'De Kleine Aarde' ('The Small Earth'), a foundation/NGO and a national centre for sustainable lifestyles, since 1972
Address: Klaverblad 1, Boxtel, Holland. www.dekleineaarde.nl for footprints www.voetenbank.nl
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The cities of Amsterdam and The Hague calculated their footprints in 1997 and 1998 using different methods. Thus their results were not comparable, and a new project The Global Ecological Footprint developed using the method of William Rees and Mathis Wackernagel, Canada. The aim was to calculate the impact of lifestyles on the globe, expressed in hectares. Thus illustrating the limited carrying capacity of the earth and the necessity fair allocation of global resources of food, wood, energy etc.. The project separates between the consumption footprint per capita per year.
and the production footprint of a municipality and looks forward to measuring footprints of products and services.

Participating municipalities:

Bergen op Zoom (65.000 inhabitants))	*Footprint 4,53 ha*
's-Hertogenbosch (130.000)	*Footprint 4,62*
Den Haag/The Hague (441.000)	*Footprint 4,46*
Leidschendam (37.500)	*Footprint 4,73*
Nieuwegein (63.000)	*Footprint 4,73*
Pijnacker (22.500)	*Footprint 4,87*
Wymbritseradiel (16.000)	*Footprint 4,61*
Zoetermeer (110.000)	*Footprint 4,80*

Cooperating partners:

- *Foundation Boog, The Hague (mainly discussion partner)*
- *De Kleine Aarde (The Small Earth),Boxtel (project management)*
- *Thijs de la Court, Haarlem (model development)*
- *Van Hall Institute in Leeuwarden (calculations and model development)*

Financial support:
Dutch Ministry of Environment
Commission for International Cooperation and Sustainable Development
the Provinces Noord-Brabant and Zuid-Holland
the eight Municipalities

Collection of data and calculation of the local footprints:
It was hard to find local figures on local consumption. Even the data on energy use were hard to get. Therefore a national system of 5 income groups was used and combined with the consumption data of these groups. These were based on national

investigations and available from the Dutch Central Bureau of Statistics (CBS) and the National Institute of Public Health and the Environment (RIVM). The estimated consumption was divided by global yields for the production, and thus a system was found that is comparable with the first footprint method developed by Wackernagel and Rees in Canada (1996). The method was applied during 1999 in 8 municipalities and the results are given above.

Another model for footprint calculations was applied in two of the municipalities (Bergen op Zoom and Nieuwegein) during 2000. This model is based on a representative poll, using a set of 13 specific consumption questions. The method results in slightly bigger footprints in both municipalities. That might depend on the use of recent, real figures on consumption, but also on the fact that the two methods are quite different.

Public campaigns using joint materials with quick footprint scans (10 min), discussions between representatives for the involved municipalities, lessons at secondary schools and discs for calculation of personal footprints (30 min) have also been introduced <www.voetenbank.nl>.
Every aldermen and also every section of the local government, is responsible for a part of the total global footprint of the municipality. This information will be extended with ideas and examples for every section in order to show how the local government can provide a better infrastructure for the development of sustainable lifestyles.

Some conclusions

- It is much easier to calculate the national and personal footprints than those of a city or town.
- Differences between footprints of cities and towns in the Netherlands are small, and the results may not pay the extra work to collect local data. Along with changes in the municipalities differences may, however, grow and thus motivate the extra work. It is quite possible to initiate local campaigns based on the national per capita footprint.
- The best combination for estimation of municipal footprints may be direct information on energy use from the energy companies and a limited poll using 10 crucial questions.
- We might need a European approach towards the energy companies to get the right of access to the energy consumption figures per year, for every quarter of cities and towns.
- A Walk of Fame project may be useful, including an exhibition and the calculation of footprints of 5 major groups of people, among them the members of the Dutch second chamber

2) Local Ecological Footprint in Navarre & other experiences in Spain

Departamento de Medio Ambiente, Territorio y Vivienda del Gobierno de Navarra (Spain).
May – November 2000
Contact person: Dr. Rafael Tortajada <**rtortajm@cfnavarra.es**>
http://www.cfnavarra.es/MEDIOAMBIENTE/Indexnoflash.html

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Geography and administration
The investigation was carried out in the Foral Community of Navarre, north of Spain, west of the Pyrenees. Area 1 million ha with mountains and humid climate. 530 000 inhabitants (1998). A dynamic, open economy based on industry with export of manufactured goods and an import of raw materials, intermediate goods and equipment. One of the most important among the 17 Spanish autonomous communities, with a *per capita* income some 16.3 percent above the Spanish average.
A local ecological footprint was estimated for the municipality of Tudela, the capital of Ribera Tudelana county, south Navarre, with 27 000 inhabitants.
Regional institution: Department of Environment, Land and Housing including the Local Agenda 21
Finance: Department Environment, Land and Housing, Section for Urban Environment (Mr. R. Tortajada), Department of Environment (Mr. J.I. Elorrieta, Mr. J. Marcotegui).

METHODS

a) Data Collection for calculation of the EF of Navarre

Information was obtained from interviews and forms sent to different administrations and institutions at local, regional and state level. Information was also compiled from and generated within the framework of the Environmental Audit of the municipality of Tudela (2000). The undertaking of this latter study also meant that interviews were carried out and that forms requesting information were sent to different administrations, supply companies and diverse organisations.

Table 1. Main sources of information

Institution	**Information requested**
Institute of Statistics of Navarre Government of Navarre	- Import and export of products classified under the TARIC[1] and CNAE[2] codes - Demographic data - Economic structure of Navarre and Tudela
Directorate General for Agriculture, Livestock and Food. Government of Navarre	- Data on the production and productivity of the agricultural, livestock and forestry sectors - The total surface area covered by arable land and pastures - Forestry production and productivity - The distribution of land-use in Navarre and in the municipality of Tudela
The Department of Industry and Labour. Government of Navarre	- Consumption and energy production according to energy sources and sectors
The Department of Public Works, Transport and Communications. Government of Navarre	- Data on the structure of transport and traffic. - The surface area covered by transportation and communications infrastructures
The Office for Territorial Wealth. Register Section for Territorial Wealth	- Plots of industrial use and associated areas in the Catastro of Navarre and Tudela
Energy supply companies	- Energy consumption according to sources and sectors in the municipality of Tudela
The Town Council of Tudela	- The vehicle fleet of Tudela
The National Statistics Institute. Government of Spain	- Fish consumption

b) Calculation methodologies

The *per capita* consumption of the main categories of products were listed, and a combination of world and local productivity was used for calculation of the footprint components as previously made for Catalonia and Barcelona. An additional calculation was included using only world productivity.

The total ecological footprint was calculated according Wackernagel, M. and Rees, W. (1996), by summing up the *per capita* surface area required, classified under the

[1] *TARIC: Tarif Integré Comunitaire*

[2] *CNAE: Código Nacional de Actividades Económicas ('National Code of Economic Activitites')*

categories of ecologically productive land: arable land, pasture, forest, built-up land, energy and productive sea.

c) Calculation of the local footprint in Tudela
Once the value of the ecological footprint was calculated for the region, the ecological footprint was estimated for the city of Tudela. An extrapolation of the regional profile on consumption was combined with specific calculations for certain consumptions: energy and build-up land – (see table 2).

Table 2: Productive Land and activities linked to the EF of Tudela

	Activities				
Productive Land	**Food**	**Housing and Services**	**Traffic**	**Commodities**	**Total activities**
CO2 absorption	0.1127	0.1690[3]	0.5198[4]	0.4584	**1.2600**
Built-up land		0.0331[5]	0.0204[5]	0.0038[5]	**0.0572[5]**
Arable land	0.5646			0.0000	**0.5646**
Pasture	0.1092			0.1331	**0.2423**
Forest				0.3933	**0.3933**
Productive sea	0.9873				**0.9873**
Total Surface areas	**1.7738**	**0.2021**	**0.5402**	**0.9886**	**3.5047**

d) Strategies for reduction of the regional/local EF
The study proposed a series of strategies for the reduction of the ecological footprint in Navarre establishing two different scenarios.

e) Some conclusions

There is limited availability of information on internal commerce and scarcity of information on consumption at a local level. There are problems to find local data on energy consumption, especially for traffic, and some extrapolations from regional data are necessary. The incorporation of more intense agricultural/forestry production systems at regional level – frequently with a greater environmental impact – can represent an apparent reduction of the ecological deficit.
The investigations in Navarre and Tuleda benefited, however, from big interest at the level of the local government and its Agenda 21, and several new and special investigations were available.
Similar conclusions have been drawn from footprint calculations in Catalonia/Barcelona, Andalusia/Seville, Balearic Islands, Basque Countries/San Sebastian

3) Experiences from local ecological footprint calculations in Finland

Association of Finnish Local and Regional Authorities
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The Association of Finnish Local and Regional Authorities has made a free of charge calculation programme for Finnish municipalities for estimation of their Ecological Footprints (designed by consultant Mr. Niko Nyman).
Calculating Ecological Footprints at local level in Finland started in 1996 when seven municipalities were recruited to a pilot project and the basic method developed. First results came in early 1999. The present calculation programme was developed in 2000 (the EFs for the year 1995). The calculations are now updated for 1999.

There are results from ten municipalities
with the cities/towns of

- Helsinki (551123) (inhabitants in parentheses)
- Espoo (209667)
- Tampere (193174)
- Vantaa (176386)
- Kuopio (86575)
- Mikkeli (46669)
- Kouvola (31614)

- Riihimäki (26106)
- Hirvensalmi (2683), a municipality
- Ristiina (5185), a municipality

The cities of Joensuu (51514) and Kotka (55238). are in progress with their calculations.

Method

The method used is based on two main phases: firstly the EF of an average Finn for a certain year is calculated using an Excel spread sheet. The sheet was originally received from Mathis Wackernagel and compared to the one used by him and Lillemor Lewan for Sweden. It is made even more detailed to suit Finnish circumstances. Besides being more detailed, some changes have been made

- national averages are used for footprints of consumption based on arable land, pasture and forest (those products which are not produced in Finland, such as coffee and rice, are of course calculated by global yields);
- the forest part of the ecological footprint is calculated in slightly different way (a detailed description in the annex);
- embodied fossil energy in net trade has been corrected to match the Finnish situation (50 % of the total embodied energy in net trade is fossil);
- the calculation is transparent concerning energy (all fossil, hydro, bio and nuclear energy are put together in the energy component of the EF);
- the footprint factor for nuclear power is not the same as for fossil fuel. One of the most powerful features of the EF is its connection to real biogeophysical processes. This is lost if the fossil fuel factor is used for nuclear energy;
- no sea area is included in the municipal footprints, because conceptually it is far from ecologically productive land. If a sea area is included, it also actualises some general problems of indexes.

In a second phase *local* data are being collected for built-up land and energy. For food consumption and commodities national averages are used (except build up land for commodities). Local differences in these categories are assumed to be so insignificant that gathering of local data is irrelevant. In other words, data related to built-up land for housing, traffic, commodities and services, energy consumption (except embodied energy in commodities) and existing ecological capacity are based on the local situation.

It has been possible to link the average Finnish energy consumption to different activities (food, housing, traffic, commodities and services) on the basis of some Finnish studies on total energy consumption in households and on primary energy consumption in Finland. Table 1 shows which of the EF components that are based on national averages (light grey) and which on local data. (dark grey). The national built-up land is not split into different activities because such information is not available at national level. Similarly, forest is not divided into housing and commodities.

TABLE 1. National averages (light gray) and local data (dark gray) used in local calculations of ecological footprints, year 1995.

	Activities/consumption					
Land use categories	food	housing	traffic	commodi ties	services	Total
energy	0,32	0,69	0,37	0,43	0,34	2,15
arable land	0,31			0,01		0,32
pasture	0,11			0,04		0,15
forest				0,47		0,47
built-up						0,25
Total	0,74	0,69	0,37	0,95	0,34	3,34

f.. Data collection and calculations

The Association of Finnish Local and Regional Authorities collects data for calculation of the EF of an average Finn. Local data are collected by the municipalities.

Land use
Detailed analyses are made in planned areas (industry and warehouses, traffic areas, technical services, sport areas, parks and recreation grounds, graveyards, etc) and approximations are used for e.g. , housing in rural areas. The calculation programme asks for data on the yields of arable land, pasture and forest. These data (besides local registers) can also be found in national master files.

Energy
Municipal energy consumption in road traffic can be obtained from the national LIISA-database. In principle this information base is not correct for the EF accounting, because the consumption is not the consumption of the inhabitants' but any consumption that takes place in the municipality. This is unfavourable for geographically large municipalities with a lot of through traffic. But it is the only information available. National averages are used for rail, waterborne and airborne traffic.

Local heating energy and electricity consumption data are given for power plants (export excluded), electricity from the national grid, regional heating and heating of individual buildings (residential buildings 150 kWh/-flatm^2/yr, others 30 % less, that is 110 kWh/flat m^2/yr).

For power plants the calculation programme asks for primary energy used (Gwh), share of different energy sources (% of coal, natural gas, oil, peat, wood chips, water power, wind and solar), share of heating and electricity power produced (%), and finally the share of consumption in housing, services and production (%). The figure for energy used in production is registered but not used, because it is embodied in commodities.

A different calculating method is suggested in an annex for the forest component of the EF (as compared to Wackernagel & Lewan)

Some conclusions

Data for the municipal land use has been surprisingly difficult to get, especially for traffic areas. The situation is similar for yields of arable land, pasture and forest. Residents' energy use in traffic is not known. Liberalisation of the energy market causes problems with data concerning local energy consumption. Municipal EF calculations can stimulate municipalities to register and provide new kind of information and statistics. The EF calculation method can help to harmonize data gathering.

The calculation programme is relatively complex with a lot of factors and coefficients. This information and part of the data must be provided nationally, or internationally. Some coefficients need further elaboration, as land area needed for hydro and nuclear electricity (at the moment international averages have been used), land required for building lots in rural and also productivity in some animal based agricultural production.

4) Ecological footprint analysis of the Turin province, Italy.

Project management: **Ambiente Italia**
Contact person:

Method

The evaluation of the ecological footprint of Turin Province was carried out according to the original methodology of Wackernagel with adaptation to Italian circumstances. For each consumption good, all the resources incorporated in its production, use and disposal were considered. Energy and resources incorporated into the good therefore refer to the total amount of energy and/or matter used and released within the product's life cycle.

The main consumption categories considered are:

1. food;
2. housing;
3. transport;
4. consumption goods,
5. services,

   each of which can be further disaggregated.

Land use is classified as:

- direct for specific biological production
- indirect for absorption of waste (green house gases).

Natural space appropriated is calculated on the basis of the real productivity levels of the area considered (productivity varies in fact remarkably with respect to both the level of economic efficiency and geo – climatic conditions).

Land Use

For agricultural production the amount of land associated with the final product used in the area considered is calculated, irrespective of the place of production. In general , the land thus obtained can be seen as the combination of various components (see the following diagram):

- land associated to local production of raw materials (LL)
- land associated to the production of imported raw materials (IL)
- land associated to the production of exported raw materials (EL)
- land associated to the production of imported final products (IL)
- land associated to the production of exported final products (EL)

It should be noted that ***the only local information refers to raw materials production***, while all other items are connected to foreign trade[6].

AGRICULTURAL PRODUCTION
RESOURCES' FLOWS

Agricultural production land (APL) is given by:

$$APL = [LL_r + (IL_r - EL_r)] + [(IL_f - EL_f)]$$

the above formula allows to calculate the hectares of land effectively used to meet consumption needs within the Province of Turin, considering consumption of both local and imported products.

Exports, on the contrary, are not included since the footprint only considers products consumed locally. On a national level, consumption of raw materials and final goods from agricultural production can be deduced from data on production and foreign trade [report 1, table 2a of the annex].

On a provincial level, data on total amount and yield per ha are only available for a few products [report 1, table 2a of the annex].

Where available, provincial data have been used; for the rest, national Italian data have been adjusted by means of a conversion factor equal to the ratio between consumption within the Province of Turin and national consumption. Thus one can obtain a proportionality factor (K) linking the average Turin Province inhabitant's consumption to that of the average Italian using data from survey carried out by Istat (Italian Institute of Statistics) on households behaviour in the various areas of Italy [Report 6, table 12 of the annex]:

The difference between consumption (estimated) and production (Istat data) makes it possible to evaluate whether production itself exceeds consumption or not. In the first case, the imported

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[6] *It should further be noticed that a combination of the first three elements accounts for the portion of land needed to make the final good locally.*

surplus footprint was added to that of local production[7]; in the latter, no addition was made to the footprint

Translating consumption amounts in kg into footprint hectares implies dividing the first by the relevant yields:

- local yields for the consumption of locally produced goods [Report 1, table 2b of the annex]
- Italian yields for Italian production data [report 1, table 1 of the annex]
- average global yields for imports [Report 1, table 2a of the annex]

In the case of average global yields – the degree of approximation due to use of global yield is evident. To reduce the error, the agricultural products that mostly affect footprint calculations have been identified and their origins traced. The most important geographical areas of origin have thus been traced (mainly Western Europe) for some of them (beef meat, sheep and pig meat, wool, milk, wheat and rye, animal based oils and fats, corn) and global average yield has been substituted with their specific average yield; this implied a significant change in the footprint final value.

Finally, we should allocate the direct land use footprint into the consumption categories that make up the final items of the total footprint (food, housing, transport, consumption goods, services).
Ambiente Italia has estimated the percentage codes weights for the contribution of each product, classified according to SITC *(Standard international Trade Classification)* for the various consumption categories. Once put into this allocation matrix, data on the footprint has been aggregated into four soil use categories: arable land, pasture, forest and sea.
The quota of built up land within the Province is also included in direct land use: this data has been deduced from the 1999 Land Coordination Plan, containing all General Regulatory Plans of the various Municipalities.

3.3 Indirect land use.

As already mentioned, indirect land use is associated to carbon dioxide emissions (or equivalent carbon dioxide) characterising the whole life cycle of a product: its industry production (of an automobile or of a refrigerator, for example), its management (the functioning of the automobile or refrigerator) and its disposal.

Industry production

Industry production is associated to land use in terms of the carbon dioxide emissions caused by associated energy consumption.
The first step in determining associated land is therefore that of evaluating the overall energy required to obtain the final product , irrespectively of where the latter has been produced.
Conceptually, the procedure is similar to the one adopted for agricultural production. Here, though, flows of possible intermediate products are also taken into account.

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[7] *An accurate estimate of the footprint associated to the imported surplus should distinguish between the quota of consumption goods with a national origin and the quota of those coming from outside national boundaries and subsequently use the different relative yields. Since this disaggregation was not available locally, an "average yield" has been estimated by means of weighed coefficients based on the percentage weight of imports on national consumption.*

INDUSTRY PRODUCTION
RESOURCES FLOWS

In general, energy used can be seen as a combination of various elements (see the following diagram):

- Energy associated to local production of raw materials (LE_r);
- Energy associated to the production of imported raw materials (IE_r);
- Energy associated to the production of exported raw materials (EE_r);
- Energy associated to local production of intermediate products (LE_i);
- Energy associated to the production of imported intermediate products (IE_i);
- Energy associated to the production of exported intermediate products (EE_i);
- Energy associated to the local production of final products (LE_f);
- Energy associated to the production of imported final products (IE_f);
- Energy associated to the production of exported final products (EE_f).

For production an exhaustive list of products could not be obtained; but information on the amount of labour units employed for each production item both on a national and on a provincial level is available [report 3 table 4 of the annex].
On the basis of the amount of local labour units and of Italian energy data, energy use of the local industry was estimated; such estimation was then normalised according to the effective data on provincial energy use, recorded by the Italian Ministry of Industry and Trade [report 3 table 7 of the annex].

Products disposal, both in landfills and incinerators, is accompanied by greenhouse gases emissions. Especially in the case of landfills, waste disposal implies a remarkable amount of methane, a gas characterised by a high global warming potential. Converting these substances into a carbon dioxide equivalent thus allows to calculate the wooded land needed for absorption, as already done for emissions from energy sources [report 5 table 11 of the annex].

5) Ecological footprint studies in UK

Completed projects include:
Isle of Wight
Oxfordshire
Guernsey
Project management; Best Foot Forward. Guernsey study with Liverpool John Moores University. Isle of Wight Study with Imperial College, London.

All BFF footprints are calculated using a component footprint approach. They are derived using proprietary EcoIndex™ software. The method builds components 'bottom-up' using life cycle data, rather than relying on national trade data. Information is collated from local investigations and resource flow calculations. Thus the method is more integrated into other resource accounting techniques. Resource flow analyses are typically specified for the following key consumption areas:

- Materials and waste
- Direct energy use
- Passenger transport

- Freight transport
- Food
- Water (production of tap water, not purification of outlets)
- Built (degraded) land

These are broken down into numerous further components. Care is taken not to double count impacts.

The method has recently been adapted for consistency with the Living Planet Report National accounts. The components use global yields and equivalence factors. Local biocapacity is calculated in the same manner as the LPR. A detailed component model of the UK has been constructed which is consistent with the LPR 2000 results.

BFF have also developed a USA, European and Australian online footprint calculator which uses components calibrated to the LPR 2000 compound results (see www.ecologicalfootprint.com). This is a natural extension of earlier work on personal footprint survey tools; EcoCal (1996), EcoCal for Schools (1998), Personal Stepwise (2000). Versions of these can be downloaded from the Best Foot Forward web site.

The Isle of Wight and Oxfordshire studies can be downloaded from the internet at www.bestfootforward.com.

Ongoing regional studies include footprints for Wales, London (www.citylimitslondon.com) and Herefordshire .

The method is documented, with examples, in 'Sharing Nature's Interest' (Chambers, Simmons and Wackernagel 2000). See website www.ecologicalfootprint.com for details.

6) Ecological Footprint studies in Sweden

Responsible institution A: Dept of Housing and Planning, Swedish EPA, mainly introductory experiments
Responsible institution B:
Project management: Researchers Folke et al.; Wackernagel-Lewan
The Carl Folke group focused the appropriation of land by cities in the Baltic drainage region and to some extent megacities in other areas. They showed that absorption of waste (carbon dioxide from fossil fuels, nitrogen and phosphorous from sewage treatment plants) demanded much more productive space than production of food and fibre for direct consumption. They also showed the huge areas demanded for production of feed for fish farming. There was a certain interest in these results and in the results of Wackernagel and Rees (1996) in the city of Stockholm, and an exhibition was arranged along with other environmental topics in the Natural history museum. But there was no real interest in the global situation. On the contrary focus was very much on the possibility of local supply of food, alternative energy (much biofuel) and recycling. Local studies employing the Wackernagel & Rees (1996) method were performed by consultants in connection with an EU Life supported project (SAMS –Planning with Environmental Goals, 2000) headed by the Swedish EPA and the National Dept of Housing and Planning.

In the meantime research was initiated for investigation of the local ecological footprint of the population in a river drainage area in South Sweden using the possibility to include calculations of areas for production of tap water and for some purification of drainage water from farmland (Wackernagel, Lewan, Borgström-Hansson, Ambio 1999). The results were compared to the biocapacity in the river drainage area. Use of the compound method, which is based on the national ecological footprint, in local studies in the river drainage area made the calculation of a national footprint for Sweden necessary. That was by then not made. The result of this separate calculation of the mean Swedish ecological footprint was not quite in agreement with the later result on Sweden in the Footprint of nations study (Wackernagel et al. (1999) although the same method and the same factors were used. The difference was one ha unit area in the ecological footprint of Sweden and one ha in the biocapacity. Reasons for the different results were probably use of direct Swedish national statistics and use of statistics from a different year. Thus it was clear that the use of statistical sources is most important for the results of footprint studies.

One more aim of the studies in Sweden was to coordinate the footprinting analytical methods of the Carl Folke et al group in Stockholm/Sweden and the Wackernagel-Lewan group in Lund/Sweden. This was, however not fulfilled.

Footprinting analyses in Sweden show the development of widely different approaches and results, which are not possible to compare and are badly understood between groups. A summary report of methods used and results gained was issued by the Swedish EPA and the National Dept of Housing and Planning within the SAMS (see above) project (Lewan 2000, An English version for the internet is planned). The report includes results from studies of ecological footprints and available biocapacities in the southernmost administrative county, Skane and its around 30 municipalities/cities which were analysed in one series using the compound method (national footprint x population) for analysis of the ecological footprint. The results were compared to local biocapacities. The report also includes results on ecological footprints and biocapacities calculated in another series using the same method in eight municipalities/cities from different parts of the country including the very south and the very north..

The compound method is easy to apply once the mean national footprint is calculated. This should be calculated in one and the same series as for other countries using international statistics for one and the same year. With access to the Excel spreadsheet for a country including consumption analyses based on Trade Statistics (STCS codes) and the national energy budget. (Wackernagel et al. 1999; the Living Planet Report 2000), specialities for different cities/municipalities can be traced using official statistics and local investigations/surveys and corrections introduced. In our studies in Sweden we found only small differences between standard of living in different parts of the country. This was based on observations on car ownership, mileage of travelling, housing etc. More detailed studies of such differences in cooperation with national statistics experts are, however recommended. Comparison between the ecological footprint of the population in an area and the existing biocapacity is useful. It illustrates the local land use, and to what extent there is space for the activities demanded by the population. A discussion about possibilities to find extra space or to offer surplus productive space can be initiated among the public and in planning.

Ecological footprint and biocapacity calculations in municipalities/cities (ca 300 in Sweden) are recommended as one of several methods for judgement of sustainable development, but there is no ongoing national project. The local authorities are informed about the concepts/tools and one of the municipalities/cities involved in the above mentioned SAMS project would be a possible candidates in a future EU project using ecological footprints and biocapacities as sustainability indicators.

7) Experiences on Local Ecological Footprints in Norway [Western Norway Research Institute] and future plans

Western Norway Research Institute is the leading research unit in Norway in the field of Ecological Footprint Analysis using the city of Stavanger as a study area (part of a local climate strategy process). Three different levels were used: the city, the household (a doctoral project) and the individual. The efforts are part of a larger project under the Norwegian Ministry of Environment individual. The studies are part of a project headed by the Norwegian Ministry of Environment for integration of global and local problems. Similar footprint calculations will also be carried out for the cities of Kristiansand and Oslo.

Additionally a new forthcoming project in Oslo will be conducted as a joint effort by the Western Norway Research Institute and ProSus (Program for Research and Documentation for a Sustainable Society/University of Oslo). The project is financed by both the Municipality of Oslo and the two research institutions, and is also meant to be included in a future European research project in the area of sustainable regional development and the use of indicators. Here only the methodological approach of the studies in Stavanger are presented.

Stavanger is the fourth largest city in Norway (approximately 110 000), County of Rogaland with an active Local Agenda 21 programme. The city has a small area - 70 km^2 - which makes it the most densely populated city in Norway. One objective is to find out how the Ecological Footprint methodology can be used in practice without too much effort on data collection.

The Western Norway Research Institute has focused on
Wackernagel and Rees

- Best Foot Forward
- The Association of Finnish Local and Regional Authorities

with a preference for the Finnish approach, including both national averages and local data (especially for built-up land and direct energy consumption for heating and transport). National yields and productivity have been used, and the calculations include data based on national per capita assessments. The Western Norway Research Institute emphasises area consumption related to energy production and carbon binding.

Footprint calculation for the city of Stavanger
The consumption is grouped into five categories based on

Food:
- national averages for the indirect energy consumption and climate gas emissions related to the consumption of food
- national averages for the consumption of areas related to the production of food

Housing:
- national averages for the indirect energy consumption and climate gas emissions related to the consumption of construction material for housing and furnishing
- local data for energy consumption (electricity, oil and fire wood)
- local data for housing area (floor space)
- local data for the household's share of the methane emissions from waste deposits

Transport:
- local transport data for private cars (based on numbers of registered cars and county calculations for average driving distance) and local bus (data from the local transport companies)
- partly local data for air travel (national averages adjusted for county specific travel habits)
- national averages for transport by boat and railway

Goods:
- national averages for the indirect energy consumption and climate gas emissions related to the consumption of fibres (with the exception of construction materials), paper, clothing, shoes, printed matter, leisure articles and services, and industrial areas

Services:
- local data for energy consumption for heating in both private and public sector
- national averages for the indirect energy consumption and climate gas emissions related to the consumption of health services, postal and telecommunication services, hotels and restaurants, public administration and other services

Footprint calculations for households

In the doctoral project for the household footprint the method is quite different. The main question is: '*How do differences in the physical living situation influence the 'housing related consumption'?*'

A survey of a large number of households in Førde, Stavanger and Greater Oslo and case studies with in depth interviews were made. The ecological footprint of households in a whole range of situations in the three cities were calculated.. The following data were included:

- Energy use for housing (heating and household appliances)
- 'Material housing consumption' (rebuilding, redecorating and indoor/outdoor housing commodities)
- Transport
- Everyday travels
- private car
- public transport
- Irregular leisure and vacation travels
- private car

- air travel

Individual footprint calculations
For the individual footprint calculations, more or less the same categories as for the Stavanger footprint calculation were used.

For the Stavanger 'climate/footprint calculator' see the 'Environmental Home Guard' (Miljoheimevernet) http://www.webskjema.no/miljokalk/).

Annex 3: The Ecological Footprint of Santiago de Chile

(Full reference: Wackernagel, M. (1998) The Ecological Footprint of Santiago de Chile, Local Env Vol. 3 No 1, p 7-25. Revised Version June 11 2001 Redefining Progress, Oakland, CA USA www.rprogress.org)

The methodology used in the above paper is summarised here as it is one of the few published studies which shows how National FoN data can be adapted for use at the SGA level using the capital of Chile, Santiago de Chile as an example.

Calculations for the National EF and BC of Chile are listed in the FoN and LPR reports and, as for other nations, an Excel data spreadsheet is available from the Redefining Progress web site (www.rprogress.org).

For comparison of the national and local consumption patterns and estimation of SGA footprints a consumption x space use matrix was constructed. Then the consumption data, energy budget and consequent demands of space categories in the national EF are reallocated into human activities like housing, transports, etc. which are more easily connected to lifestyles and thus more easily compared and adjusted to local circumstances. For the whole country the reallocation of consumption data into human activities must not change the total result, i.e. the average EF for Chile, 2.4 ha. Specific adjustments for Santiago de Chile resulted, however, in an EF of 2,6 ha, see Table 1 below.

Good local information was not readily available in the case of Santiago de Chile. The data in the Table below are rough estimates mainly based on official information from ICLEI South America, and thus the study results do not claim to give a complete picture. Generally wood consumption was lower in the Santiago SGA as compared to Chile. All other consumption such as food and energy was higher in the capital.

In the Santiago study it was also suggested that the footprint might change by income group ranging from 0.4 ha per capita for the 10% of the population with lowest income to 12 ha for the 10% with highest income.

Table 1 shows the ‘space use’ or component matrix used for Santiago de Chile. The population of the Santiago Metropolitan Area was 4 756 663 in 1992. The total area is 791 581 ha of which 701 619 ha was protected natural area, 41 215 built upon land and 48 747 ha planned or agricultural land.

TABLE 1: Consumption – space use matrix for the average citizen of Santiago de Chile in hectares.

	fossil energy	built-up area	arable land	pasture	forest	sea	Total
Food	**0,11**		**0,35**	**0,75**		**0.24**	**1.45**
.vegetarian	**?**		0,32				0,32
.animal products	**?**			0.75		0,24	0.99
.water			0,03				
Housing and furniture	**0,04**	**0,01**			**0.11**		**0.16**
Transport	**0,25**	**0,00**			**0,04**		**0,29**
.road	0.18						0.18
.rail	0.00						0.00
.air	0.02						0.0
.coastal and waterways	0.04						0.04
Goods	**0,43**	**0,00**	**0.15**	**0,07**	**0.09**		**0.74**
.paper production	0.18				0.09		0.27
.clothes (non-synthetic)	0,00		0,02	0,07			0,08
.tobacco			0.13				0.13
.others	0.25						0.25!
Total	**0,83**	**0,02**	**0.49**	**0,82**	**0.24**	**0,24**	**2.64**