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Documentation of Klimakost

An environmental assessment tool designed for the calculation of life cycle emissions from companies, municipalities and organizations

Foreword

This document describes the methodology behind the Klimakost environmental management tool and the practical implementation of these methods in the tool.

The document is directed at the customers of Klimakost assessments and is distributed with the more to-the-point reports from the tool. We provide the report in order to give a transparent and trustworthy documentation of the method and the methodological approaches behind it.

The report requires a basic level of knowledge about environmental impacts and how they occur as well as basic mathematics skills for some of the sections.

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Trondheim, 7th November 2012

MiSA AS

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Introduction

Klimakost[1] is a model for developing life cycle emission inventories for entities such as households, companies and municipalities, in a cost-effective, yet still methodologically concise manner. The tool was developed to analyze the amount of *direct and indirect* emissions resulting from a given consumption of goods and services. This type of perspective is normally referred to as life cycle assessment (LCA), since it aims at accounting for all emissions occurring from consumption, all the way back to extraction of raw materials and fuels. The innovative aspect of the tool is the use of economic data to evaluate the consumption of goods and services using Environmentally Extended Input-Output Analysis (EEIOA). Using economic data – available in standardized financial accounts, in most cases – makes this a time-efficient and cost-effective way of developing emission inventories.

The tool has been developed by MiSA – Environmental Systems Analysis[2]. The founders of MiSA all share a background from the Industrial Ecology Program[3] at the Norwegian University of Science and Technology (NTNU). This program is internationally renowned for its development and application of LCA and EEIOA based methods, and for numerous publications in international peer-reviewed journals, which strengthen the program's position on both a national and international level. Using our knowledge within LCA and EEIOA modeling, we have developed Klimakost to be a state-of-the-art tool in line with recent developments standards such as ISO 14064 (ISO 2006) and the corporate value chain GHG- protocol (WRI and WBCSD 2011).

Growing concern about indirect emissions

Currently almost all emission inventories focus only on direct emissions from the studied organization, company, nation or industry. There is, however, a shift in initiatives to include life cycle considerations so that supply chain effects are included and accounted for. These effects are often referred to as *indirect effects*. In this way, the consumer is allocated more of the responsibility for emissions, and focus is pointed toward the intricate cause-effect chains between consumption and production.

Early focus on indirect emissions includes studies within input-output analysis and early process-based life cycle (Leontief 1970; Bullard, Penner et al. 1978). These studies paved the way for later interest in indirect emissions and cause-effect chains of energy demand. During the 1990's the concept took off and the number of approaches and studies within the field quickly expanded. At present there is a continued rapid development of the methods used in calculating indirect emissions. International trade studies now clearly demonstrate the global nature of environmental problems. This link is especially relevant for the climate issue, where it is shown that emissions embodied in international trade are significant, and that the existence of "pollution havens" may seriously affect initiatives on reducing emissions if these indirect effects

[1] www.klimakost.no
[2] www.misa.no
[3] http://www.ntnu.no/indecol

are not accounted for. For single products, the life cycle perspective is included in so-called environmental product declarations of type III (ISO 2000) and other initiatives (British Standards 2008). The ISO standard builds upon the more general standards for life cycle assessment (ISO 2006; ISO 2006). The latter, however, only includes greenhouse gases, thereby excluding numerous other important pollutants. In the past few years, there has been an increasing focus on the same perspective for organizations and companies, resulting in, for instance, the Greenhouse Gas Protocol (WRI and WBCSD 2004; WRI and WBCSD 2011), which was used as background for the new standard for organizational carbon accounts ISO14064-1 (ISO 2006). It is our claim that any serious assessment needs to include not only direct (scope 1) emissions and purchase of energy (scope 2), but all other indirect emissions defined as "scope 3" by the GHG protocol.

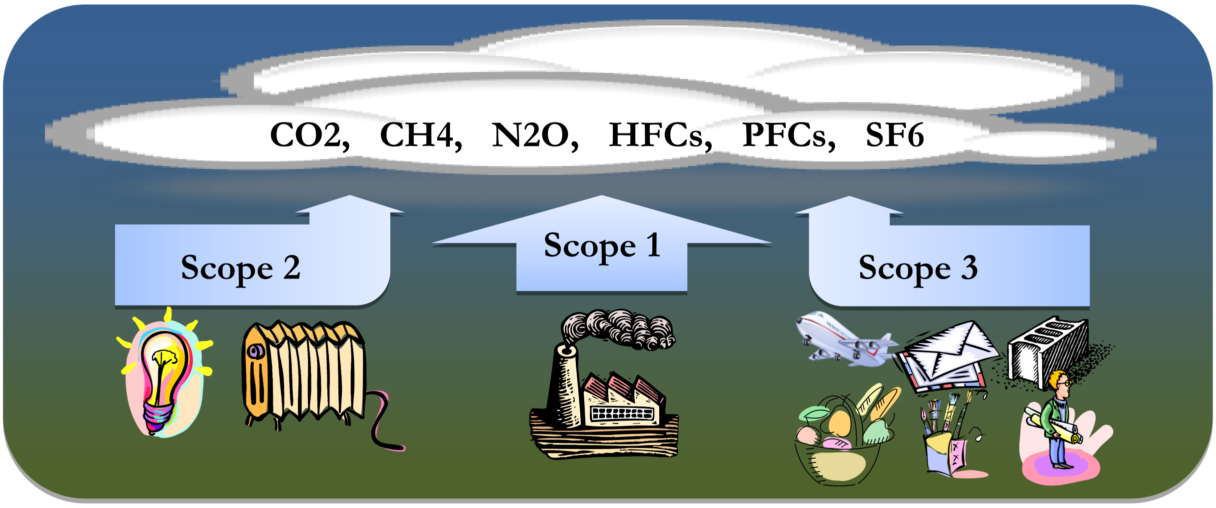

Figure 1: *Different scopes of emission accounting as described by the GHG Protocol (2008).*

Environmental management

Klimakost is intended for use in the mitigation strategy of an organization or company. The Klimakost domain is indicated in Figure 2. The main aim of Klimakost is to reveal the complete "footprint" emission inventory to be able to target the most contributing elements, so that resources are not spent on less important parts of the system. This misdirection of resources is already evident in current practices, since a major part of emissions are overlooked when a full life cycle perspective is not adopted. Actions undertaken to reduce scope 3 emissions are often quite randomly selected, without previous knowledge of the contribution to the complete footprint. By employing the top-down procedure as shown in Figure 2, such poor prioritizations are minimized.

The work on calculating and reducing emissions is a continuous process. Because of this, the Klimakost model is developed to effectively being able to integrate more specific LCA data on the most important contributions, and on effects of mitigation strategies, as indicated in Figure 2. To ensure a continuous process of developing better environmental inventories and mitigation strategies, it is vital to include this refining and reassessment process in environmental management systems. MiSA has developed Klimakost to comply with the environmental management system criteria in ISO 14001. Klimakost also fulfills the requirements of both ISO 14067 and the corporate value chain GHG protocol. MiSA will provide continued environmental consulting throughout the process of implementing the Klimakost model in your organization or company.

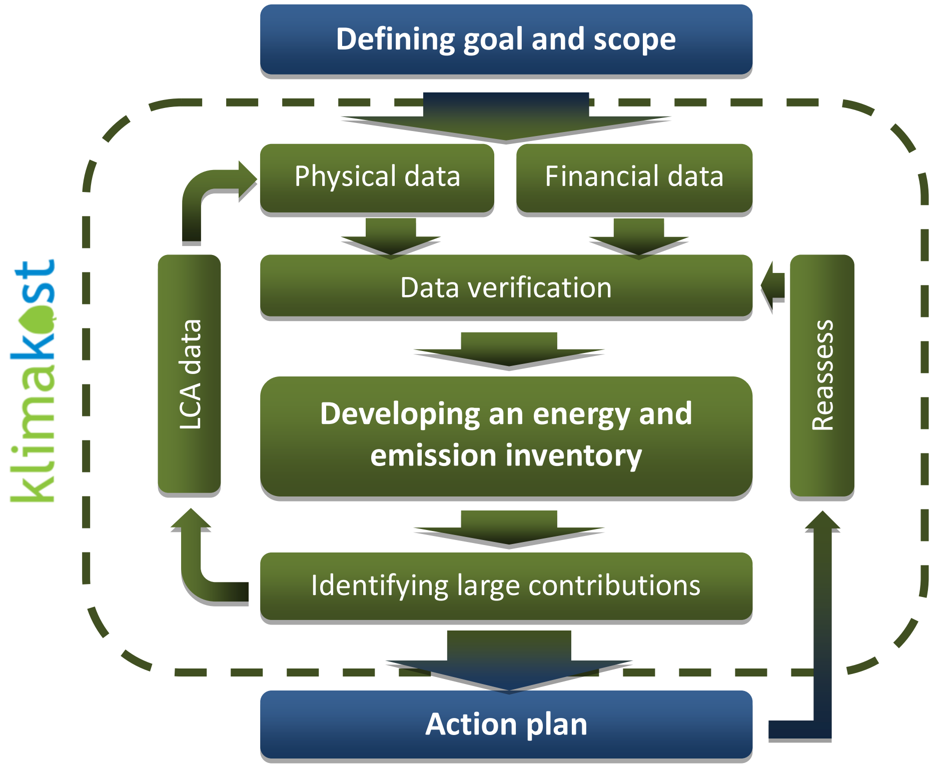

Figure 2: *The role of Klimakost in management and improvement of environmental impacts.*

Green procurement strategies

A natural extension to the Klimakost model has been related to green procurement strategies. In Norway, the law on public procurement[4] states that all public entities should consider the environmental consequences of their purchases. This is a potential driver for these entities to develop consumption based emission inventories in order to target the most important purchases with respect to environmental footprint. MiSA has shown that the current environmental requirements cover less than 1/3 of the total GHG footprint (Pettersen and Larsen 2011) indicating a large potential for improving the direction of the requirements.

Companies have also begun to address their value chain through e.g. CSR related initiatives. Here, it is not only green procurement strategies that could be important, but also more specific involvement in how suppliers and sub-contractors perform environmentally. Many companies have the ability to influence the production technology used by suppliers. A complete scope 3 analysis as Klimakost provides will capture the effect of these initiatives, thus providing companies with a wider set of mitigation options compared to only focusing on the direct emissions.

[4] http://lovdata.no/all/tl-19990716-069-0.html#6

Methodology

Klimakost is based on state-of-the-art developments within the field of environmental systems analysis. It is therefore necessary with an understanding of the toolbox presently available within the field. All the methods presented here may be used to analyze both single products and organizations as a whole. Regardless of which application is being used, special attention must be given to functional differences and the goal and scope of the assessment, in order to ensure consistency.

Life-cycle assessment

Life-cycle assessment (LCA) is the assessment of environmental impact throughout the life-cycle of product systems. The cornerstone to the life-cycle approach is the understanding that environmental impacts are not restricted to specific locations or single processes, but rather are consequences of the life-cycle design of products and services. The product life-cycle covers all processes from extraction of raw material, production, use, and final treatment or reuse (Baumann and Tillman 2004). The combination of a quantitative approach and a holistic perspective leads to trade-offs being clearly demonstrated in LCA results. It is a systems tool well-suited for environmental decision making. Having been referred to by many names through its development (Baumann and Tillman 2004), LCA has, in the last four decades, evolved from the idea of cumulative resource requirements into a scientific field that includes emission inventory assessment methods (Heijungs and Suh 2002) and environmental cause-consequence modeling (Udo de Haes, Finnveden et al. 2002).

The LCA methodology has been standardized step by step. The SETAC working groups[5] and other institutions have been vital in this process. The development of international standards has been an important driver for defining the methods of LCA. The first set of standards were published by the International Organization for Standardization in 1997 (ISO 1997), with a revised version complete in 2006 (ISO 2006). For a more thorough description of the historical development of LCA, see Ayres (1995) and Baumann and Tillman (2004). The standardized LCA framework defines four consecutive stages, as illustrated in Figure 3 .

Goal and scope

The first stage of LCA consists of defining the aim and boundaries for the assessment, and the choice of methods for inventory and impact assessment. The goal and scope stage includes defining the functional unit (FU). The functional unit is a quantitative measure of the functional requirement(s) that the product or service is designed to fulfill. It is the basis for comparison in LCA and is used to evaluate the relative performance of alternative product systems.

Life-cycle assessment may be conducted for various purposes, such as product benchmarking, product declaration, process development and policy support. Study designs set important limitations on the ability of the study to provide answers. An important issue in this respect is the functional unit. Other issues include the level of inventory completeness, temporal and spatial considerations, and impact and inventory assessment approaches.

[5] http://www.setac.org/

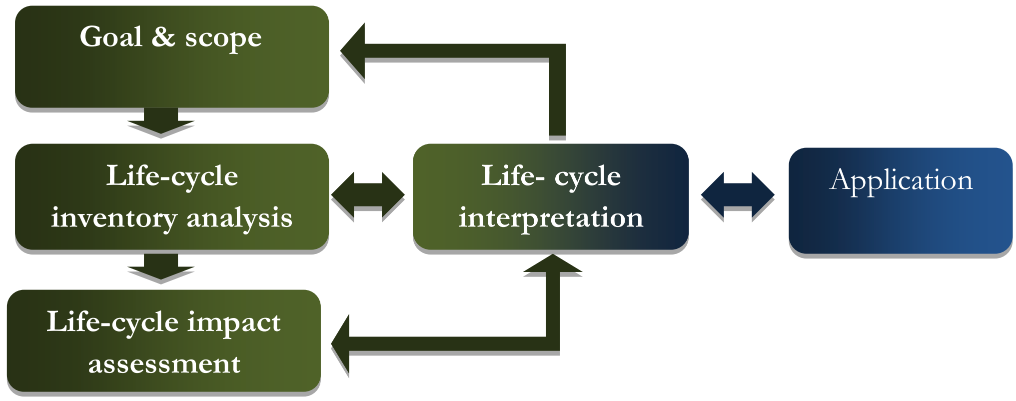

Figure 3: *Outline of the stages and iterative approach of life cycle assessment (ISO (2006))*

Life-cycle inventory analysis (LCI)

The second stage consists of establishing an inventory that describes the environmental interventions that arise from the product system. Environmental interventions are inputs of resources from the environment to the product system (i.e., energy and material resources), and outputs to the environmental of adverse effect that the product system produces (i.e., emissions). The inventory is scaled to the functional unit.

Life-cycle impact assessment (LCIA)

Once the inventory of environmental interventions is established, the interventions are translated to environmental impact indicators in the third stage of LCA. Quantitative scores are achieved by application of characterization factors that describe the relative potential of each intervention. An example is CO_2-equivalents which are used to aggregate the global warming potential.

The life-cycle impact assessment is divided into three consecutive steps. First, environmental interventions are separated according to their cause-and-effect chains, termed impact chains or impact categories in LCA. Interventions may be input-related, i.e., energy and material extracted from the environment, or they may be output-related, i.e., emissions made to the environment. Second, impact scores are aggregated for each impact category by multiplying inventory mass flows with their respective characterization factors and summing these for each of the impact chains. The last step of life-cycle impact assessment is the weighting of impact scores relative to each other. Weighting compares and evaluates the relative importance of different environmental issues, such as comparison of acidifying air-emissions with consumption of material resources.

Life-cycle interpretation

The final stage of LCA is the interpretation of results. Vital in the interpretation stage is the consideration of uncertainty. Other aspects include the effect and validity of the selected impact assessment methods to fulfill the stated purpose of the study, and the potential bias introduced by inventory sources and approach. The re-visitation of methodological choices validates the outcome of LCA analyses and increases the relevance of LCA for decision support.

Environmentally extended input-output analysis

Input-output analysis (IOA) was initially developed by Leontief (1936) as a method to study the interrelations between the sectors in an economy. In the beginning of the seventies, he formulated a framework to extend the analysis with environmental information (Leontief 1970). The basis of this analysis is to use information contained in national economic statistics, in combination with data on emissions from the various sectors in the economy, to calculate all of the direct and indirect emissions occurring from an arbitrary final demand placed upon the system.

The economic consequences of spending 1 NOK on, for example, gasoline, may be calculated and traced through all of the interconnected sectors of the economy in an infinite, yet converging, series of demands between the sectors. Once the economic outputs required to support the production of this 1 NOK purchase of gasoline have been calculated, the resulting vector of economic activity in each sector may then be multiplied with emissions intensities for each sector to give the total (life cycle) emissions occurring in the production of 1 NOK worth of gasoline.

Recent developments are numerous: on multi-regionality (Peters and Hertwich 2008; Hertwich and Peters 2009; Wiedmann, Wood et al. 2010), hybridization (Treolar 1997; Nakamura and Kondo 2002; Suh, Lenzen et al. 2004; Suh and Huppes 2005; Stromman and Solli 2008; Lenzen and Crawford 2009) , sub-national levels (Lenzen, Murray et al. 2007; Larsen and Hertwich 2009; Wiedmann, Lenzen et al. 2009; Larsen and Hertwich 2010; Lenzen and Peters 2010; Larsen 2011), and on corporate carbon Footprinting (Wiedmann, Lenzen et al. 2009; Larsen, Pettersen et al. 2011) A thorough overview of the different IOA applications to environmental analysis is provided by Minx et al. (2009).

Hybrid life-cycle assessment

While process-based LCAs require relatively specific types of data, it has been criticized for leaving out significant portions of the emissions that occur in the system (Lenzen 2001; Norris 2002; Strømman, Solli et al. 2006). This issue is referred to as cut-off and is particularly true for processes far upstream and service-based activities. On the other hand, input-output analysis is ideal for including emissions from all types of activities without any cut-offs, since it is based on an aggregated model of all existing sectors of the economy. However, it lacks the detail provided by LCA. Because of this, several authors describe the use of LCA and IOA in a hybrid approach, trying to utilize the benefits of both approaches, thereby retaining the completeness associated with input-output analysis, as well as the specificity offered by process based LCA. Various variants of these approaches are described by several authors (Treloar, Love et al. 2000; Suh and Nakamura 2007; Michelsen, Solli et al. 2008; Stromman and Solli 2008).

Computational structure

The computational structures of life cycle assessment, input-output analysis and hybrid LCA are more or less identical. The idea is to calculate emissions occurring as interconnected processes are instigated by a final demand. Several authors give detailed descriptions on the computational structure of LCA (Heijungs and Suh 2002; Peters 2007) . We will give a short description of the computational framework in the following. Beware that notation may differ from other sources as there is no general agreed-upon nomenclature that apply to all methods. We start by defining our system of production processes, economic sectors, or both (in hybrid analyses) as a matrix Z, containing the flows of energy, materials, money etc. between the different entities (from now on referred to as "nodes").

$$Z = \begin{pmatrix} z_{11} & \cdots & z_{1j} \\ \vdots & \ddots & \vdots \\ z_{i1} & \cdots & z_{ij} \end{pmatrix}, \quad x = \begin{pmatrix} x_1 \\ \vdots \\ x_i \end{pmatrix}$$

Each element z_{ij} of the matrix denotes the flow of the product from node i into the production of output from node j. In addition, we have information on the total output from the system, x. If the total output from each node is described by the vector x, a normalized system may be constructed by dividing each column in Z by the corresponding total outputs: $A = Z\hat{x}^{-1}$

We then can define a final demand by the vector: $y = \begin{pmatrix} y_1 \\ \vdots \\ y_i \end{pmatrix}$

Setting up a balance we know that the total output of the nodes subtracted the amounts consumed by the nodes themselves, should equal the final demand y.

$$\overbrace{x}^{\text{total output}} - \overbrace{Ax}^{\text{consumed by nodes}} = \overbrace{y}^{\text{final demand}}$$

The total output x from each node needed to fulfill the final demand, in addition to all the intermediate demand from other nodes, can then be calculated by

$$x = \overbrace{(I - A)^{-1}}^{\text{Leontief inverse}} \; y$$

The Leontief inverse, L, is a matrix describing multipliers for all nodes in the system, so that a column j in L gives the total direct *and indirect* outputs in all other nodes in order to deliver a unit final demand from j. Similarly, emissions can be treated the same way where the matrix S is total emissions and where an element s_{kj} contains the emissions of substance k from node j.

$$S = \begin{pmatrix} s_{11} & \cdots & s_{1j} \\ \vdots & \ddots & \vdots \\ s_{k1} & \cdots & s_{kj} \end{pmatrix} \rightarrow F = S\hat{x}^{-1}$$

Normalization by dividing of total node output (x) gives a matrix F of emission intensities per unit output from each node. The total emissions, e, occurring due to an arbitrary final demand from the nodes can now be calculated by:

$$e = Fx = F(I - A)^{-1}y$$

Introducing the characterization factors according to the description in section Life-cycle impact assessment (LCIA) on page - 7 - gives the opportunity to translate the emissions data into more understandable environmental impact potentials, d. The characterization factors are contained in the matrix C, where an element c_{lk} describes the contribution of emission type k to impact category l. The calculation of d then becomes:

$$d = Ce = CFx = CF(I - A)^{-1}y$$

The Klimakost model

The background model

Although life cycle assessment is often targeted towards analyzing products or functions, the very same techniques may just as well be used to analyze the impact of entire organizations or businesses. Klimakost uses process-LCA techniques in combination with EEIOA for its calculations. A main requirement for Klimakost is an EEIO model of the background economy for the studied entity. We have constructed a model for Norway following the procedure described in section Computational structure on page - 8 -, using national accounts data for Norway from 2005 (Statistics Norway 2009), and emissions data (Statistics Norway 2009).

Emissions and impact categories

The following pollutants and energy sources are included in the Klimakost background model. Note that LCA data hybridized into Klimakost from SimaPro will increase the level of detail on pollutants significantly on the imported processes.

GHG gases	Other gases	Emission related energy use
CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, CO	NO_x, SO_x, NH_3, PM_{10}, NMVOC	1) Coal & coke, 2) motor gasoline, 3) aviation gasoline, jet kerosene, 4) kerosene, light fuels oils and heavy dist., 5) auto diesel, 6) marine gas oil/diesel, 7) heavy fuel oil, 8) natural gas, 9) LPG, 10) other gas, 11) wood & waste, 12) electricity and 13) district heating

For the characterization of emissions, we use factors from the well-recognized method CML 2 Baseline 2000 v.2.04 (CML 2004) to calculate impact potentials within global warming (expressed as CO_2-equivalents), acidification (expressed as SO_2-equivalents), human toxicity (expressed as 1,4-di-chloro-benzene-equivalents), photochemical oxidation (smog) (expressed as C_2-H_2-equivalents). In addition, we report particulate emissions (PM_{10}) as a separate category.

Imports

Although a few complete multiregional EEIO models (Peters and Hertwich 2006; Peters and Hertwich 2008; Hertwich and Peters 2009) exist, these models usually suffer from issues related to lack of data and updateability. Klimakost therefore applies a simplified EU27 import assumption regarding imports to Norway. The EU27 data are frequently updated and in the same format as the Norwegian EEIO model.

Preparations for use

The model is in basic prices, which means that for any use with data in purchaser prices, we need to know or estimate the trade and transport margins, as well as the taxes. In addition, we must perform inflation adjustments to the base year of the input output model. These steps are vital in order to produce a model that can be used in Klimakost assessments. The price adjustments are all performed at an industry specific level, using appropriate data from Statistics Norway. The consumption of fixed capital is internalized in the model by assuming this to follow the average structure of the fixed capital formation in the given year.

Klimakost in use

Klimakost have been applied to a wide range of different cases, ranging from households to national economies. We therefore describe some key elements regarding the use of Klimakost at the different levels.

Municipalities

One key feature of Norwegian municipalities –including counties- is their common reporting format, KOSTRA[6]. This ensures consistent reporting from the municipalities to the federal government and statistics office. The municipal accounting system uses a set of pre-defined 3-digit commodity categories defined in KOSTRA. Municipalities also report according to function (service areas) in the 3-digit standard form defined by KOSTRA. In addition to the pre-defined KOSTRA accounting, most municipalities have an additional level of detail both on purchases and service areas in their internal accounting system, enabling a more detailed analysis when necessary.

A simplified schematic overview on the calculation process is illustrated in Figure 4. First, for 78 different service areas, the 34 KOSTRA purchasing categories are matched to the 58 IO sectors. In addition, we add physical data covering scope 1 and 2 contributions, typically kWh of electricity use and liters of fuel for transportation. Then, the Klimakost model is used to derive emissions intensities. Finally, a complete emission inventory covering 34 purchasing categories and 78 service areas are derived by reversing the matching of IO sectors and KOSTRA purchasing categories.

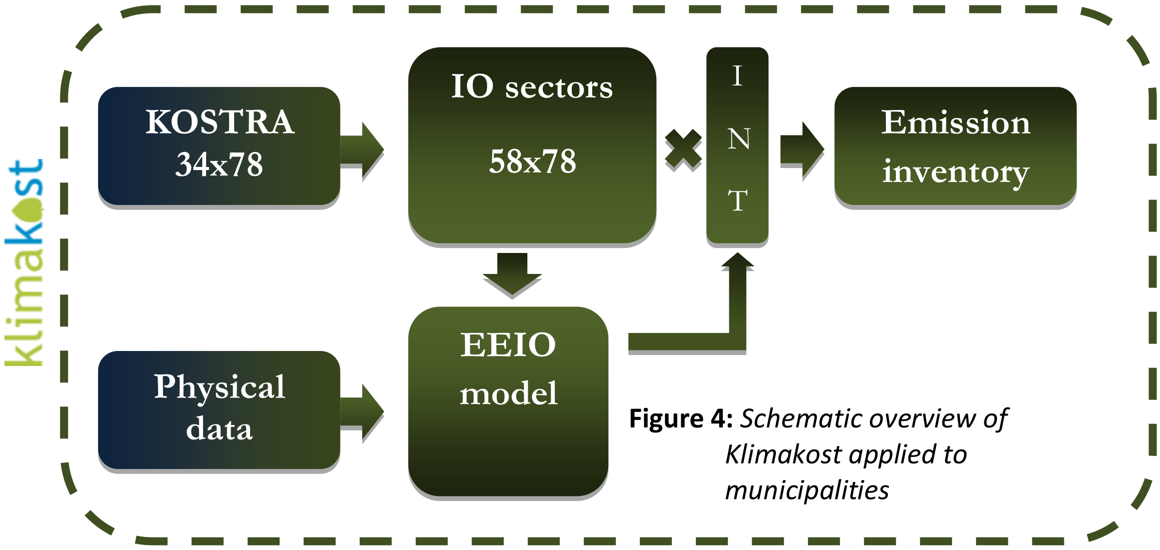

Figure 4: *Schematic overview of Klimakost applied to municipalities*

Companies

Following the application of the Klimakost model to municipalities, we began in 2009 to investigate how Klimakost could be used for companies and organizations. The results were positive; Klimakost would be effective for developing an emission inventory for these entities as

[6] http://www.ssb.no/kostra/

well. As with municipalities, businesses also have standardized their financial accounting. Therefore a similar procedure as that illustrated in Figure 4 for municipalities can be applied to companies and organizations by substituting the KOSTRA data with another financial accounting system. Similar to municipalities' service areas, we find that companies often divide their activities into different departments, enabling a per-department emission inventory that has been found to be useful when aiming mitigation strategies. The use of physical LCA data for companies and organizations are often found to be sector specific. For some sectors, it is useful to develop complete LCA modules in SimaPro. One example of this is the "Norske Bygg" SimaPro module to be used in emission inventories covering the building and infrastructure sector.

Households

MiSA has also applied the Klimakost model to calculate emission inventories at the household level. Consumer data for households are available through the national accounts and the national survey of consumer expenditure (SCE). The SCE only has 2000 respondents, so any breakdown of household footprints to the municipal level has to be performed by using some scaling parameters such as household income. A pre-study of household carbon-footprint calculations, and description on possibilities to apply this at a municipal level, has been conducted for the city of Oslo (Solli and Larsen 2009). Calculations have also been used to assess low-carbon settlements. MiSA has also contributed to the official Norwegian household carbon footprint calculator[7].

National level

Although most studies using Klimakost are at a sub-national level, we have also applied the model in the calculation of the environmental footprint of the Norwegian economy. These calculations are often used to provide a different perspective compared to more traditional geographic/Kyoto based perspectives, as it includes the indirect emissions of Norwegian consumption. This makes the calculation more robust in handling changes in industry activities and also outsourcing of industry, and hence performs better as a measure of sustainability. Similar calculations at the national level have also been used in a research project (Peters and Solli 2010) of the Nordic countries. MiSA has constructed EEIO models for several EU countries, thereby adapting Klimakost to calculations for a wide range of entities.

Uncertainties

Klimakost is, without a doubt, the most precise and cost-effective tool of its kind in Norway. To our knowledge, no other systematic and *methodologically consistent* tools exist at present. A few uncertainties related to the use of Klimakost are, however, important to address:

- Uncertainty in the background model (possible errors in national statistics)
- Uncertainty in the price adjustments (basic prices and yearly adjustments)
- Uncertainty connected to varying practices in accounting book-keeping
- Uncertainties caused by the aggregation of sectors and the matching of these

[7] http://www.klimakalkulatoren.no/

Results from selected Klimakost studies

Municipal level

Most Klimakost studies have been performed at the municipal level. The model has also been widely applied to other public entities[8]. In 2012, MiSA developed a carbon footprint based GHG inventory for the city of Oslo, covering all municipal service areas. Figure 5 shows the GHG emission inventory divided into aggregated service areas and aggregated purchasing categories. Results clearly show the large differences in the structure of the carbon footprint from one service to another. These differences are effectively captured because of the standardized structure in the reporting of the economic KOSTRA numbers. This is one of the strengths of the Klimakost model.

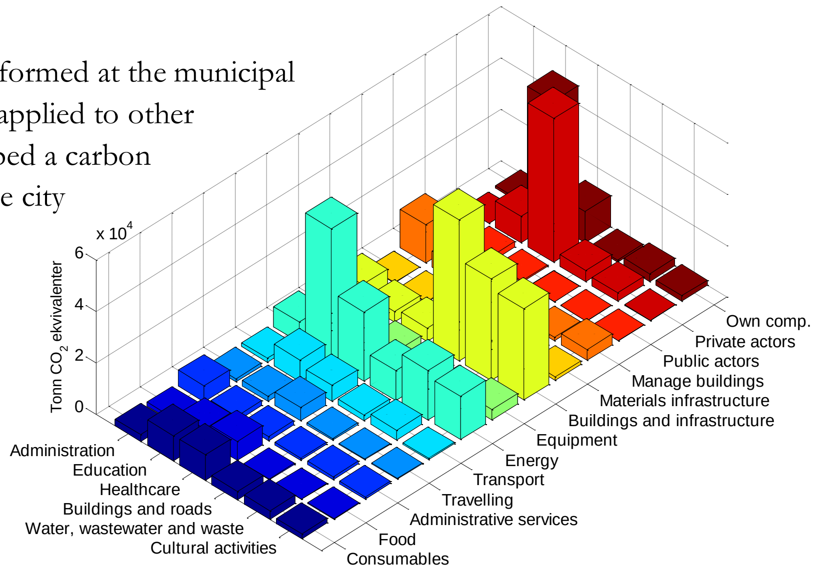

Figure 5: *GHG inventory, city of Oslo*

Municipalities in Norway have reported expenditures in the KOSTRA format since 2001. This enables us to effectively generate time series while dividing the emission inventory into contributing service area, or – as illustrated in Figure 6 – by contributing purchasing category.

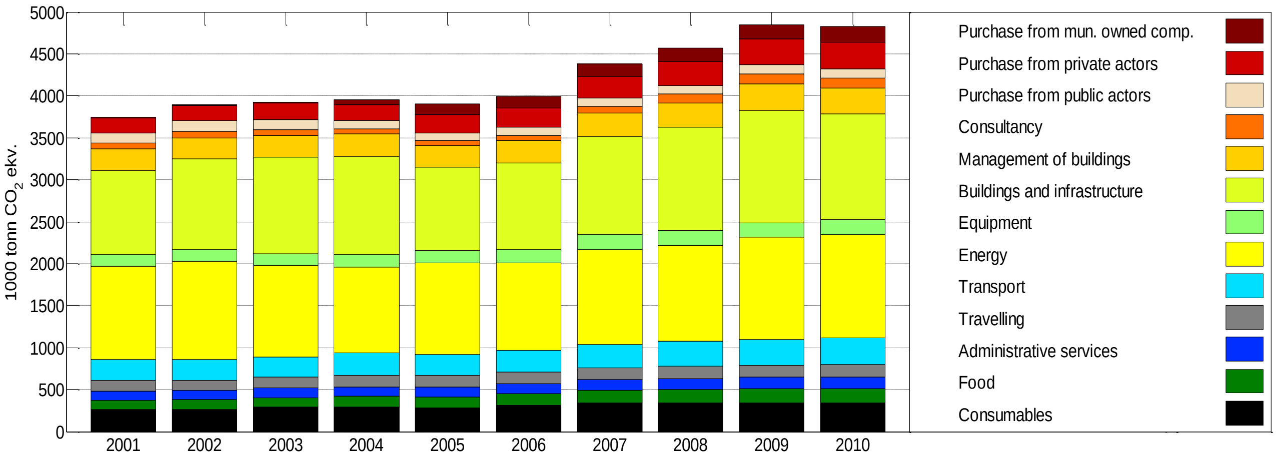

Figure 6: *GHG inventory time series, all municipal activities*

MiSA has also developed several interactive calculators based on the calculations of municipal GHG inventories. These calculators are available online at the Klimakost website: **www.klimakost.no**

[8] http://www.misa.no//prosjekter/klimaregnskap_offentlige_virksomheter/

Company level

The Klimakost model has been applied to several of companies and establishments[9]. In 2012, we also used the model to analyze our own carbon footprint at MiSA. The results were interesting and provided MiSA with several target areas to on which to focus.

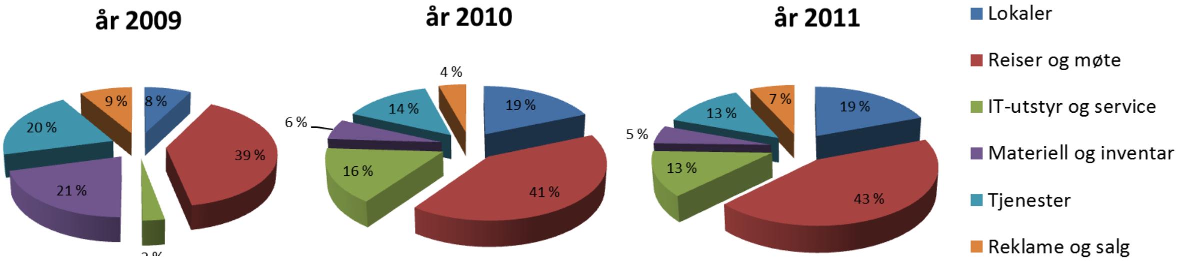

Figure 7: *The carbon footprint structure of MiSA*

Results can also be benchmarked to IO sector averages to further investigate the both the environmental performance and to identify target areas. Results in Figure 8 illustrate this by comparing MiSA to the average carbon footprint of the research and development sector in Norway. In total, MiSA was slightly below the average of the sector; however, emissions related to travels were found to be higher compared to the sector average.

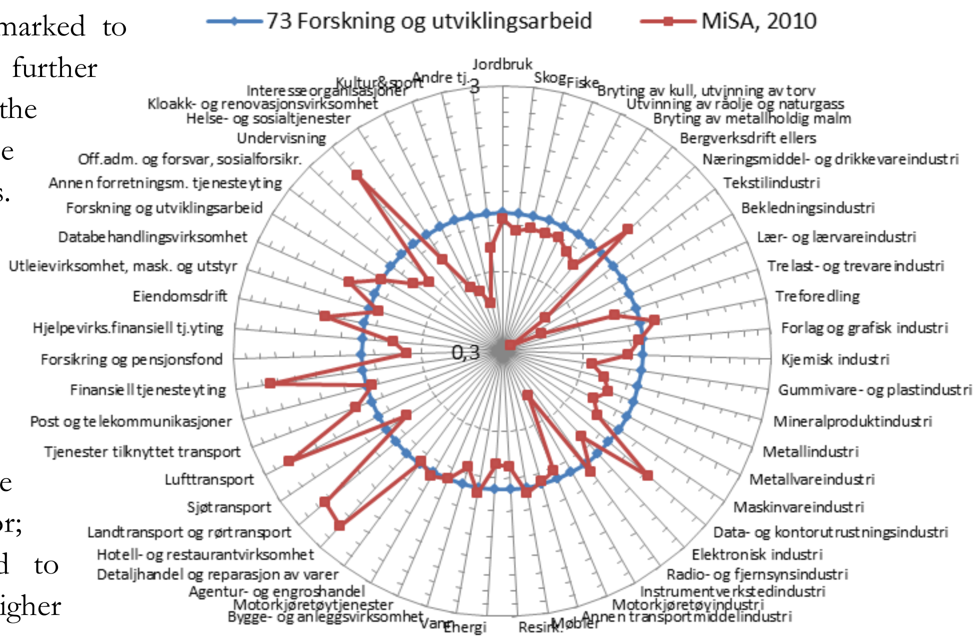

Figure 8: *MiSA carbon footprint compared to sector average*

Klimakost further provides a range of possibilities in displaying the emissions inventory in ways to provide decision makers with the necessary information to effectively direct their strategies. Below we exemplify this by illustrating two standardized figures from the Klimakost for a Norwegian entity; the supply chain distribution of GHG emissions together with the weighting of different GHG emission to the total carbon footprint of a Norwegian entity.

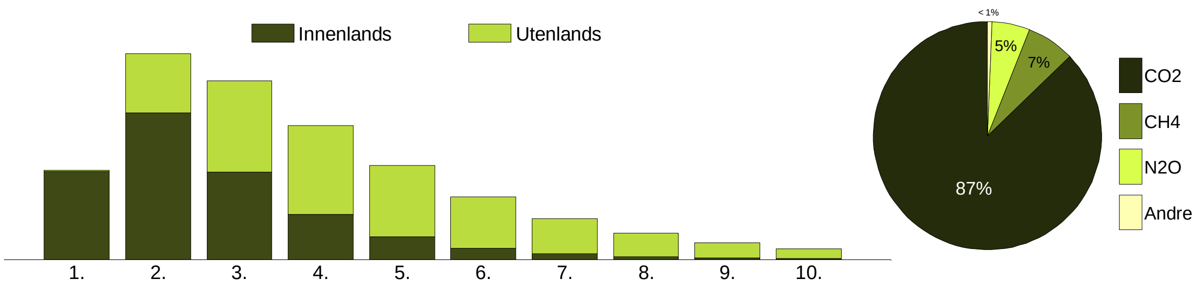

Figure 9: *Results from Klimakost, supply chain distribution (left) and GHG contributing emissions (right)*

[9] http://www.misa.no//prosjekter/klima_og_miljoeregnskap_bedrifter/

Household level

MiSA has, in several projects, applied the Klimakost model to evaluate the environmental footprint of individual households. The Brøset project[10] in Trondheim is one example. Here, the Klimakost model is used to measure the carbon footprint of low-carbon communities. In most cases, the household calculations rely on consumer expenditure surveys. This also enables us to compare carbon footprint per capita calculations to different types of households, as shown in Figure 10.

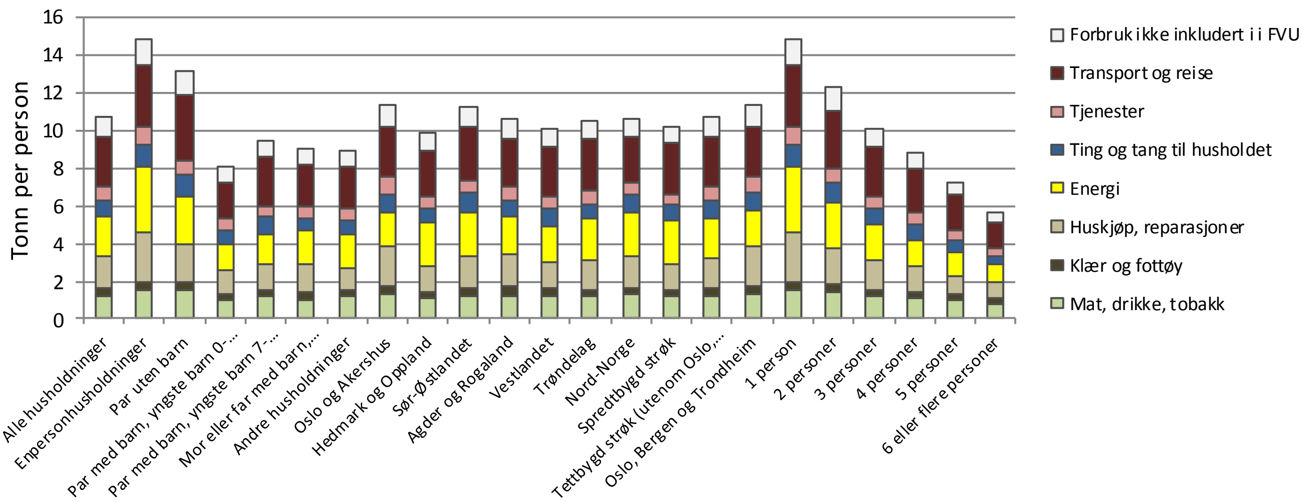

Figure 10: *Carbon footprint per capita for different household*

The detail in the expenditure surveys also enables us to investigate the carbon footprint per purchased item for different classification of households. In Figure 11, we illustrate this by identifying the most emission contribution purchasing categories for three geographical classifications. Results show that sparsely populated areas have a higher contribution from fuel for transportation and energy. However, large cities have a higher overall consumption level that leads to a higher carbon footprint in most other categories.

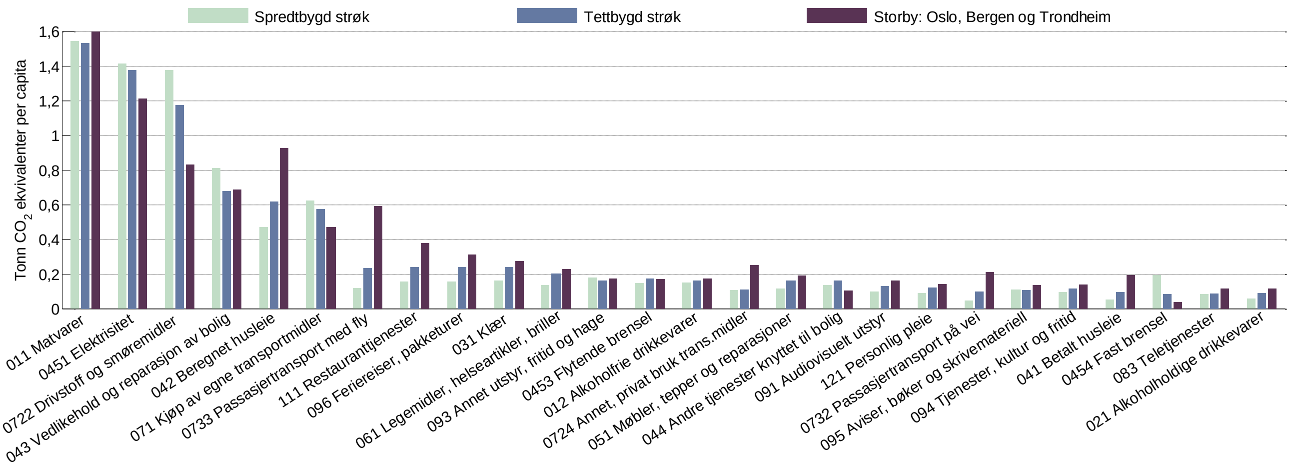

Figure 11: *The carbon footprint of different purchasing category*

[10] http://www.trondheim.kommune.no/gronnbybroset/

National level

The Klimakost background model can be uses to calculate the emission footprint of Norwegian consume. In Figure 12, this is illustrated by dividing the footprint into environmental impact categories caused by different final consumption categories. Note that Norwegian exports are not included in this figure. In most cases, indirect emissions from household consumption comprise the largest share of the total footprint. The exception is the particulates (PM10) category; here, direct emissions from household heating, mainly from the use of wood fuel, are the highest contributing element.

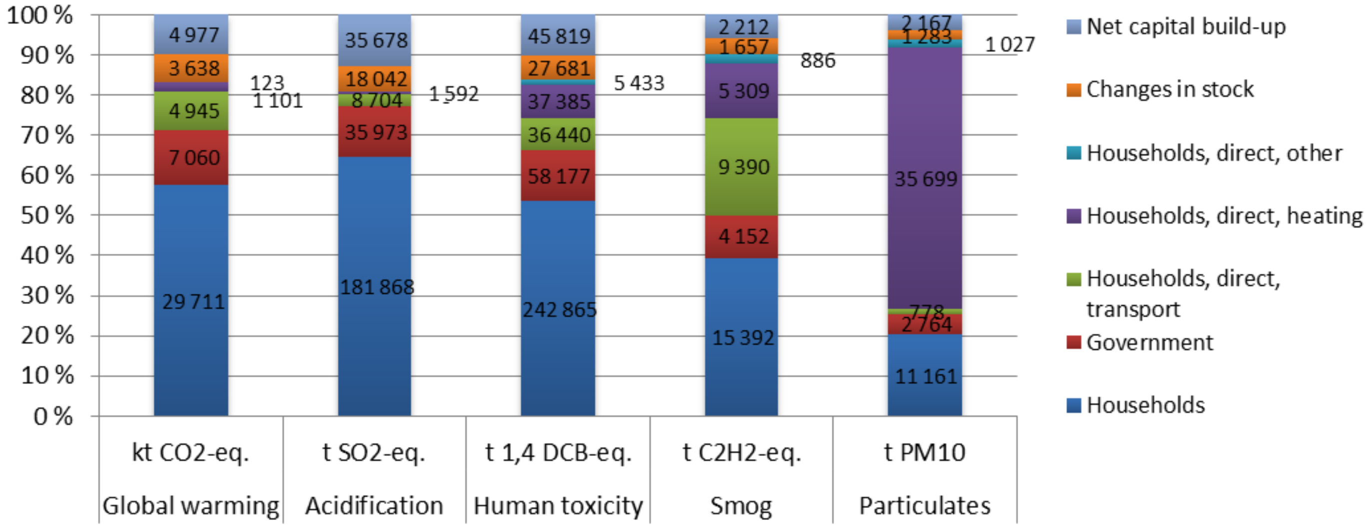

Figure 12: *Emission footprints for Norwegian consumption*

The background model can also be used to trace emissions in the supply chain. This is very useful to evaluate cause-effect relationships. Often, one has to investigate several steps in the supply chain to find the focus area of mitigation strategies. In Figure 13, a Sankey diagram is used to illustrate the carbon footprint resulting from household consumption of food and agriculture/fisheries products. The largest contribution comes from the food production sector. However, most of these emissions can be traced to the production of agriculture and fishery products. Similar illustrations can be made for all sectors in the Klimakost background model at several levels of detail.

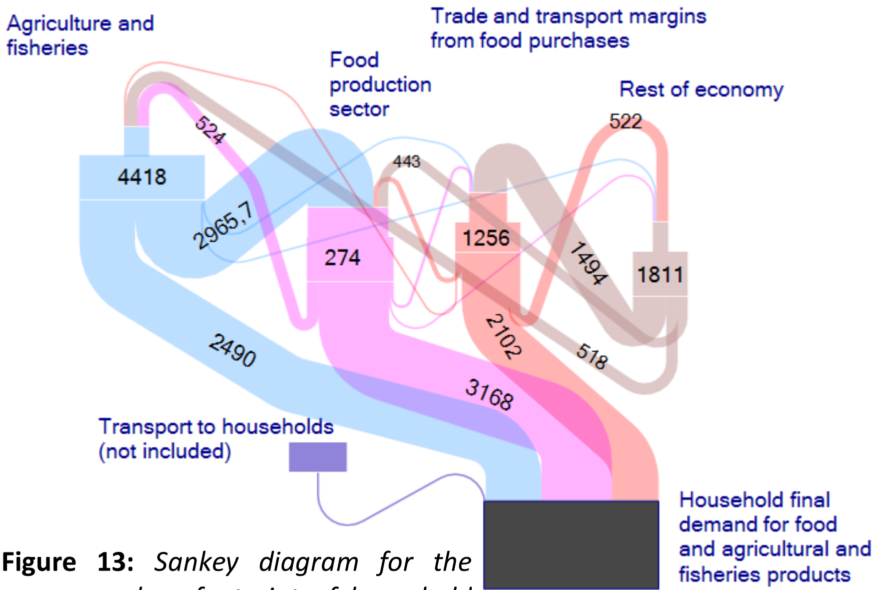

Figure 13: *Sankey diagram for the carbon footprint of household food demand*

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