Report prepared for "One Tonne Life project" - Method for estimation of a families' greenhouse gas emissions

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1. General approach

The purpose of the One Tonne Life project is to illustrate what a lifestyle with emissions limited to 1 tonne of CO_2-eq/capita/yr would look like today. The idea is to calculate the emissions as though everybody generated emissions at roughly the same level as the family. For this reason we do not take into account the marginal impact of the family's consumption on emissions. Instead we use average emission data to calculate the emissions from electricity, consumption of goods etc. We try to capture most of the effects that an altered consumption pattern would have on emissions. Thus, we do not only consider direct emissions from fuels used by the family, for instance, but also emissions from fuels and electricity consumed by the companies that produce the goods and services consumed by the family.

We only take into account greenhouse gas emissions in this project. Of course there are other environmental problems and other social issues to consider as well, even if we do not take them into account in this project. However, the fact that one particular activity, according to our figures, has a lower carbon footprint than another does not necessarily imply that we recommend that that activity should be favoured. There may very well be other concerns that we think should override a small difference in carbon footprint.

Methods used

In general there are two main methods of assessing the environmental effects of consumption, Life Cycle Analysis (LCA) and Input Output Analysis (IOA). These two methods have different merits. LCA studies products and the input required for the production of those products. By using process data, the energy required – as well as methane and nitrous oxide emissions – are calculated. Emissions are traced backwards to a given point.

In an IOA the economic transaction between sectors is studied. For instance, a factory buys oil to produce chairs. However, all emissions are not allocated to the factory, but also to the companies that buy chairs from the factory. In an IOA all emissions for a given year caused by a sector are in principle accounted for. Hence the electricity used by the consultants constructing the factory is also allocated to the chair factory. The calculations are only made for economic sectors and not for certain products. This means that the IOA gives cruder estimates than an LCA does, but on the other hand the accounting is more comrehensive.

Furthermore, IOA indicates an emission factor per SEK consumed in a certain sector. Hence a more expensive product automatically leads to higher emissions than a cheaper one if they are produced within the same sector. Thus, brand-name clothing gives higher emissions than cheap copies, even though an LCA would estimate approximately the same level of emissions. On the other hand, there are not – and will never be – LCA data available for all those millions of products that are for sale in the world. Therefore, IOA provides a good approximation when other data is not available.

To calculate the family's emissions profile we use a combination of LCA and IOA. Combining these methods may be problematic as the scope of the methods may be different, so double accounting or missed accounting may occur. Still, as the family will use specific new technologies, such as an electric car, it would not be possible to represent this in an IOA analysis since there is no electric car sector. Furthermore, LCA data are not available for all goods and services. To calculate the emissions we use LCA data for transportation, housing, direct electricity use and food, whereas IOA is used to estimate emissions from other types of consumption.

In addition to the potential problems of combining two different methods, all data used for our calculations incorporate substantial uncertainties. Nonetheless, our method can provide a rough estimate of the actual emissions generated by the family.

Energy mix

The IOA data calculate the amount of energy used per SEK of electricity, fuels and district heating. Thereafter, emission factors have to be applied to the energy used. The IOA data (SCB, 2006), assume that all goods and services are produced in Sweden. Naturvårdsverket (2008) on the other hand tried to trace import and export of products at a fairly detailed level. This is of importance as the electricity used in Sweden on average causes low levels of greenhouse gas emissions, whereas the electricity generated in most other places in the world is largely coal-based.

In this project we use a simplified calculation. We assume that all services are produced in Sweden and therefore use the Swedish energy mix. Around 36% (in monetary terms) of the goods in Sweden are imported and the rest are produced domestically. Most of the import originates from the EU. We use a weighted average of Swedish (Energimyndigheten, 2009) and European (IEA, 2010) energy mix to calculate an emission factor for goods, see Table 1. For services we use average intensity for Sweden for electricity and fuels, whereas we use data for Stockholm for district heating (Svensk fjärrvärme, 2010).

Table 1. Emission factors for energy used for goods and services production

	Electricity (g CO_2-eq/MJ)	Fuels (g CO_2-eq/MJ)	District heating (g CO_2-eq/MJ)
Services	9	60	35
Goods	50	62	-

Allocation

We want to monitor the emission profile for the family on a weekly basis. However, this may become problematic as an investment one week may look like the family caused very high emissions that week, although the service or product may be utilized for a very long time period. For that reason we allocate emissions from consumption over a longer period of time. The allocation period differs between different kinds of goods and services. For instance, the house has an allocation period of 100 years, whereas emissions from the production of the car are allocated over a period of 15 years.

Scenario

The family cannot control all their emissions since the goods and services they buy are still produced using fossil fuels. Therefore we also study the effect of a future energy system. We use 2050 as an indicative year and assume that the energy system will by then have undergone significant changes. We assume that average emissions in Sweden will by then be down to 1 tonne CO_2-eq per capita. Out of this budget we assume that 750 kg is emitted from the energy sector and the rest from waste handling and food production. We assume that the economy's energy-efficiency has increased by 30%. We can then estimate emission factors for energy supplies, as can be seen in Table 2. Those emission factors imply a power system almost entirely based on renewable and/or nuclear energy, implying that fuels largely consist of biofuels and that district heating is generated from waste heat and biomass. When we calculate this scenario, we also assume that methane and nitrous oxide emissions are reduced by 50% compared to today's levels.

Table 2. Emission factors in a one tonne/capita scenario

	Electricity (g CO_2-eq/MJ)	Fuels (g CO_2-eq/MJ)	District heating (g CO_2-eq/MJ)
Services	1	5	5
Goods	1	5	5

2. Housing

For the construction of the house LCA data are provided by Widheden (2010). Not all parts of the house have the same allocation period, so we divide the emissions as in Table 3. The resulting emissions for the entire family is estimated at 573 kg/CO_2-eq.

Table 3. Emissions from construction of the house

	Total (t CO2-eq)	Allocation (yr)	Emissions/year (kg CO2-eq/yr)
Household utilities	2	15	133
House	44	100	440
Total			573

IOA shows that maintenance and repairs to a house cause average emissions of 150 kg CO_2-eq/person and year (SCB, 2006). However, as the family moves into a totally new home, these emissions will not occur for the family during the project's duration. Nonetheless, the building will need maintenance in the long run, and for that reason 150 kg CO_2-eq/person is added for the maintenance as a template.

3. Transportation

To calculate the production emissions from the electric car we combine data for a Volvo C30 with an LCA for a 280 kg Li-ion battery. We further assume that 40% of the steel is produced from recycled material and 25% of the aluminium, although we do not take into account recycling of the car. This gives an emission value of 5700 kg CO_2-eq (Volvo, 2010), and is allocated over 15 years. Emissions caused by services and repairs will be calculated by IOA data, see Table 8. The energy used by the car will be electricity only and those emissions will be calculated as for other electricity use.

The family will, however, also use other modes of transport. In such cases all family members will have to log their journey and mode of travel using a *Commute Greener!*[TM] CO_2 calculator. *Commute Greener!*[TM] calculates the distance travelled using GPS, and the family logs their mode of transport. In Table 4 we have compiled emissions factors for different

modes of transport. Lönngren (2010) estimated emissions factors for the Stockholm region. Buses in Stockholm city run on ethanol or biogas (Solerud, 2010). For that reason we reduce the emission factor by 50 % (Concawe, 2006) in the inner city. For data on intercity trains we use data from IVL (2002) and apply emission factors for the average Swedish electricity system in Table 1. We assume the same emission factors for metro and local trains.

Table 4. Emissions per person/km for different modes of transport

Mode of transport	(g CO_2-eq /person km)
Bus, Stockholm city (ethanol)	14
Other buses, Stockholm region	27
Metro	0.7
Local train	0.7
Intercity train	1.5
Intercity bus	20
	(g CO_2-eq/km)
V50 Diesel	115

4. Electricity

Electricity generated from the solar PV cells on the house is not assumed to generate any emissions apart from the emissions generated during their construction. The production of the solar cells, allocated over 30 years, constitutes 400 kg CO_2-eq per year for the family. Electricity bought and sold by the family is measured by Vattenfall on a daily basis. If electricity is sold, it is assumed that Swedish electricity mix is replaced, see Table 5. Emissions from bought electricity are calculated based on origin, see Table 5. Compared to other LCAs wind power has higher emissions per kWh compared to many other studies (Weisser, 2007). This is partly explained by the fact that grid connection for offshore wind power is included in the LCA data, and that actual production data is used. As wind power is a rather new technology, the actual production in the starting phase is often lower than was expected. Nuclear LCA emissions, on the other hand, are a bit lower than is commonly reported in the literature. This may be explained by the fact that Vattenfall mainly uses uranium enriched by centrifuges rather than diffusion technology, and that low carbon electricity is used in most of the uranium mines. Still, the emission levels for all technologies are very low compared to conventional coal fired electricity, where the emission level is around 1000 g CO_2-eq/kWh.

Table 5. Greenhouse gas emissions for electricity produced by Vattenfall

Power source	(g CO2-eq/kWh)
Swedish electricity mix	9.0
Hydropower	6.0
Nuclear power	3.7
Wind power	17

Sources: Vattenfall AB Generation Nordic (2008) Vattenfall AB (2010a; 2010b),

5. Food

To calculate greenhouse gas emissions from food consumption we use LCA data and form rather broad food categories. The data used in the project can be seen in Table 6.

Table 6. LCA estimate on greenhouse gas emissions for different types of food. Allocation period for all food is assumed to be one week.

Food category	kg CO_2-eq/kg product
Beef, lamb and game meat[1]	26
Minced meat (mix of beef and pork)	16
Pork, ham, meatballs	6.1
Sausages and poultry	1.8
Fish, fresh and frozen	3.1
Shellfish and conserved fish	1.8
Cheese	9.3
Other dairy products and egg	1.5
Readymade dish with meat	2.5
Readymade dish with fish	1.5
Readymade dish, vegetarian	0.8
Pulses and lenses	0.7
Fresh fruit and berries from Nordic countries	0.4
Fresh fruit and berries, imported	0.7
Vegetables, fresh	0.7
Vegetables, frozen	1.3
Root vegetable	0.2
Exotic fruit and vegetables, aviation	11
Margarine	0.9
Vegetable oils	2.5
Bread and crispbread	1.7
Cookies and biscuits	1.8
Potatoes	0.1
Pasta, couscous etc	1.0
Rice	2.0
Cereals	1.0
Flour, grain	0.6
Soda	0.3
Juice	1.3
Coffee	3.1
Candy and ice-cream	1.8
Tinned food, readymade sauces	1.0
Jam	0.8

[1]Game meat consumed below the Swedish average of 2 kg/capita/year is assumed to cause emissions of only 1 kg CO_2/kg meat

The LCA data used include emissions from production, processing and distribution. We compile data from Carlsson-Kanyama and González (2009), Floren et al (2007), Wallen et al (2004) and Wang et al 2010, to estimate emissions per kg of product.

Restaurant meals

As IOA data only provides very aggregate numbers, there is one greenhouse gas intensity for all restaurants. To be able to account for different choices of food at the restaurant we use a combination of LCA data and IOA data. Based on Katajajuuri (2009), Davis et al (2009) and Floren et al (2006) greenhouse gas emissions for lunches based on the main protein source are estimated, see Table 7. A lunch that cost 75 SEK causes around 2 kg CO_2-eq according to IOA, of which half is methane and nitrous oxide. A typical lunch consists of chicken or pork, resulting in 1.5 kg CO_2-eq according to LCA studies. We therefore assume that 0.5 kg CO_2-eq arises from the restaurant itself and activities surrounding the restaurant, which IOA takes into account but LCA does not ,. Based on this assumption we can estimate the emissions from different kinds of lunches, see Table 7.

Table 7. Estimation of emissions from meals at restaurants.

Meal	LCA data (kg CO_2-eq/meal)	IOA (kg CO_2-eq/meal)	Total per meal (kg CO_2-eq/meal)
Beef or lamb	4	0.5	4.5
Fish	2	0.5	2.5
Other meat and cheese	1.5	0.5	2
Vegetarian	0.75	0.5	1.25

6. Other consumption

For other consumption we use IOA data obtained from SCB (2006). We use the emission factors for energy-related emissions as stated in Table 1, depending on whether the category mainly represents a service or a product. To make the calculations easier categories have been summarized, the items in a category diverge by maximum 5 g CO2-eq/SEK compared to the average. The emission data also include non-CO_2 greenhouse gases and those are included in the intensity estimate; the carbon intensities are found in Table 8.

Table 8. Greenhouse gas emissions per SEK for different types of goods and services based on IOA data.

Category	(g CO_2-eq/SEK)	Allocation period
Petrol, diesel and fuel oil	207	1 week
Electronic equipment, machines, cars and bikes	21	15 years
Taxi and car rental	23	1 week
Hotel and travels	35	1 week
Electricity	40	3 month
Gas	286	3 month
Rent and payment of interest on houses	13	1 month
Maintenance, cleaning and repairs	14	1 year
Flowers and garden	113	1 year
Clothing	26	2 years
Furniture	26	20 years
Books and other goods	24	1 year
Beauty products, medicine and glasses	22	1 year
Pets, pet food and equipment for pets	40	1 year
Services and phone	6	1 month
Culture and education	13	1 month

7. Public consumption

Besides private consumption we also benefit from large amounts of public consumption. Included in public consumption are such things as schools, roads, government, hospitals and so on. It is not possible for the family to affect these emissions. Per capita emissions of public consumption are estimated at 2 tonnes CO_2-eq/capita/year (Naturvårdsverket, 2008), and this value is used as a template for the family.

8. System perspectives and caveats for the approach used

Does changed lifestyle result in changed emissions?

The purpose of the project is to study what a "one tonne life" may look like today using current but advanced technologies, if everyone tried to live a "one tonne life". However, the actual emissions from the family, since not everyone else lives like they do, may be different from the values we calculate. In the calculations we have used an average approach, so if the family changes their consumption, energy use is thereby reduced and we use the average energy mix to calculate the changed emissions. However, in reality, if there is a small change in electricity use, the technology with the highest variable cost usually phased out first. In the case of electricity, this implies that coal fired or gas fired power plants are used, even if the Swedish electricity system on average is almost carbon neutral. On the other hand there is

also a cap and trade system for carbon dioxide in Europe, which sets an upper limit on emissions from power production and large industries in Europe. This implies that the effect of changed consumption on carbon emissions is zero. However, this does not apply for changes in transportation or food consumption, where changed consumption in the system today corresponds to real changes. The larger the share of the consumption's emissions that are in the cap and trade system, the less the effect of changed lifestyles. However, in a dynamic political perspective, this is not necessarily the case, as reduced emissions from households lead to reduced prices for permits, making it easier for politicians to lower the cap further, which in the end is necessary to reach an average emission level of 1 tonne CO_2-eq per capita and year.

Waste handling

We do not explicitly account for different waste handling practices in the family. The reason is that in the LCA data used here, it is in general assumed that some of the materials in the products originate from recycled material. Thus, to calculate the family's recycling rating and then allocate an emission reduction based on its recycling behaviour would result in double accounting. Still, it may be that the family recycles more than society's average, and if everybody recycles like they do, the proportion of recycled material in products would be even larger. We estimate that this benefit is rather small, and we do not have sufficient data to estimate it.

Deforestation and carbon sequestration

Tropical deforestation is a large source of carbon dioxide emissions. Deforestation is largely driven by expanding agricultural production, in particularly cattle ranching. In addition, increased production of biofuels is estimated to cause tropical deforestation (Searchinger et al, 2008). In this kind of analysis the fact that Sweden is located far from the actual forest is of less relevance. The point is that increased consumption of beef or biofuels causes an increase in food prices, which makes it more profitable to start cultivating land that today is under forest cover. In our calculations indirect deforestation due to biofuels or food consumption is not considered, even though these links exist, though the magnitude is highly uncertain. If these emissions of land-use changes were included, biofuels would appear as a worse option and the importance of reducing beef and milk consumption would appear even more striking. However, grazing animals may also contribute to increased carbon sequestration in pasture land, which would benefit some types of meat. Still, these benefits are also very uncertain and we do not have detailed enough data from the family's consumption to take this into account.

Transportation distances and production system

We have not distinguished between products produced at different locations. You may suspect that a plastic toy imported from China would cause greater greenhouse gas emissions than the same toy imported from Denmark. We have not been able to include this aspect. Still,

transportation does in general have very little impact (less than 5%) on the total carbon footprint of products, unless aviation is used as the mode of transport. More important is the energy-efficiency of the factory and the energy mix in the overall energy system. We have not been able to take these aspects into consideration. The same goes for seasonal foods. We have not been able to represent different emission levels for food depending on season. However, as we have distinguished between Nordic and non-Nordic vegetables, buying Swedish vegetables according to season tends to cause lower emissions.

Energy-efficiency

The house that the family lives in is highly energy-efficient, but since most of the electricity used in the house originates from carbon-free technologies a less energy-efficient house would not have any major impact on the family's emission profile. However, this does not imply that energy-efficiency is irrelevant from a climate perspective. Carbon-neutral energy supply is in general more expensive than conventional fossil fuel technologies. For that reason energy-efficiency will be economically more important as energy prices increase.

Acknowledgments

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