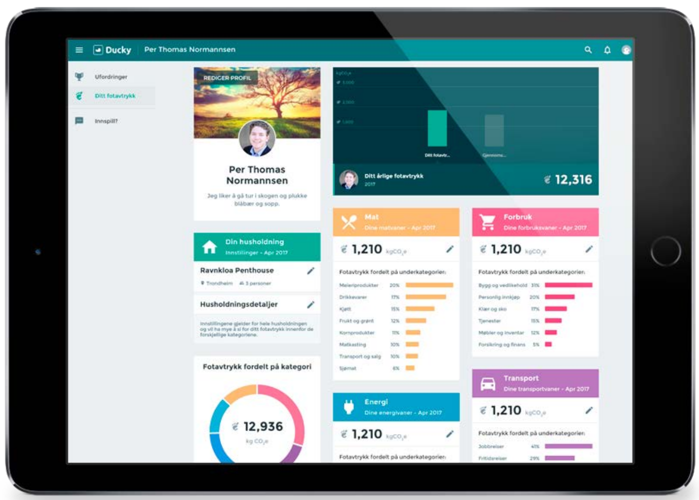
Climate calculator - documentation



Development partners:
All the calculations behind the calculator are done in a collaboration between Ducky and Asplan Viak, while design and development have been done by the Ducky team.

A special thanks to:
Department of industrial ecology at NTNU, and the department of psychology at NTNU. Together with Ducky and Friends of the Earth Norway, they were part of the research project "The people's climate research" in 2016. The project revealed the climate effect of various climate actions , and how this information could be communicated in an understandable manner. This knowledge has formed a base for this calculator.

Also thanks to Innovation Norway, Climate Kic and Skattefunn, who have been main funding partners through the development phase.

Ducky

Content

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1 About the calculator

1.1 Main aim

Our main aim with this calculator is to simplify climate data so it becomes understandable for everyone. We also want to show how all global emissions can be allocated to individual consumption of products and services, and how we, as individuals, have the power to ensure that we reach critical climate goals. To achieve this, we must continue to develop theclimate calculator until it's globally known as the world's best climate calculator.

Individual climate footprint can be tracked over time to see how we can reduce our footprints and reach important climate goals. Individual footprints will be reduced over time both when individuals improve their habits, and when industry changes in a way that our consumption has a lower impact. E.g when we buy less clothing, and when clothing manufacturers ensures that global clothing production has a lower climate impact in the future. We will update all calculation constants regularly to track industry changes, and we hope our users will update their habits accordingly.

1.2 Functionality

The calculator works in such way, that after entering the most basic household data, all other data are estimated, based on available statistical analysis for Norwegian households, and assumptions, where statistical data could be found. This means that the climate calculator can be useful and quite accurate (for quite average people), with little input. Still, the result will always improve as more input is filled in.

1.3 Personal vs. household footprint

The calculator on Ducky.no shows personal climate footprint. This means that emissions that are common for the entire household, such as heating of the house, are divided on all household members. A quite accurate estimate of the household can therefore be found, if all household members take the calculator and sum the amount of each member.

The climate calculator also calculates household emissions, but this is not shown in the user interface today. The way this is done is that the person taking the calculator gets an exact footprint, while habits of family members are estimated. In other words, all household specific input such as heating source will be used for all household members, while all individual habits are estimated as average for those members not taking the calculator. This household footprint can be shared with an API to other webpages.

1.4 API sharing

Other webpages can get access to our climate calculator. It is then possible to choose amount of input and we deliver the results for either personal or household footprints. Send an email to post@ducky.no if you are interested in having a climate calculator on your webpage. An example of such an API sharing can be found in IKEA Norway's climate campaign Start home at www.starthjemme.no.

1.5 Calculator accuracy

We have strived to make the climate calculator as accurate as possible with relying on the newest available research and literature. Therefore, we firmly believe the results as a whole are representative for the majority of the Norwegian population. We do know, however, that there are large variations in the carbon footprint in the population. Thus, the results might not always coincide with the actual carbon footprint. Furthermore, data found in literature might also vary, so our numbers could be slightly different than other sources . Nevertheless, we believe the calculator serves its purpose of estimating our user's carbon footprint and show the effect of different reduction measures.

Calculations are made currently for Norwegian households. We hope to integrate international climate data in near future.

1.6 Transparency

We have strived to make the calculator as transparent as possible. Still, the calculations made are sometimes quite complex, and it is challenging to describe it all in detail. This document presents a rough overview of how our calculations are made, and what sources we have used.

In addition, more details of important calculation data can be found under each choice in the climate calculator on Ducky.no.

1.7 How to contribute?

We will continuously improve the calculator until it is globally known as the best climate calculator ever made. To make this happen, we need good partners and collaborators. You can contribute to improve the calculator by:

- Send us feedback if you see some possibilities for improvements
- Send us suggestions for updated research that could improve the calculator
- If you are a researcher we are interested in common projects that could improve climate data, study user behavior and improve the functionality
- If you are passionate about our calculator and want to make it your job to improve it, you can apply for a position in Ducky

2 Intro to calculations

2.1 Why CO_2-equivalents?

Different calculation methods are used depending on the emission category, but all results are given in CO_2-equivalents. This means that emissions on different greenhouse gases are given in the amount of CO_2, which is needed to achieve the same impact to climate change over a 100-year time period. This is the most common unit to measure climate change impact, as used by the Intergovernmental Panel on Climate Change.

When you save CO_2-equivalents, you also reduce your impact on land use, ecosystems, water usage and other parameters. These are not calculated in detail as it would complicate the calculator too much on this stage. These effects are still described briefly under climate actions in the Ducky platform.

2.2 Calculation methodology

Calculations for household consumption are based on macro-economic input-output data, which report emissions per NOK spent on a services or products. These emissions are calculated on a national level, and we adjust them down to a household level, by comparing how much a family spends on this service or product. To adjust national data down on a household level is called a top-down approach. For the remaining categories, we apply a bottom-up approach, which means that we calculate all contributions with specific calculations on a per-product level. A relevant example is all the emissions that occur in the production and distribution of 1 kg of beef, or all emissions associated with driving 1 km with a car. In many cases, we apply a background database to include emissions happening further down in the production chain. We use Ecoinvent 3 as a basis for most calculations.

Top-down calculations	**Bottom-up calculations**
Gives an overview of greenhouse gas emissions based on socio-economic data like income and household type. The data are connected to the survey of consumer expenditure (Statistics Norway), and are compared to global emission models.	Calculates emissions to climate change based on specific activities like transport, food and energy consumption, which are then summed.

3 Category calculations

3.1 Food

In our calculations, we have used the survey of consumer expenditure (2012) from Statistics Norway as a basis. Here, the amount of yearly food consumption per person is given for various food categories. Matvaretabellen.no shows the calories content per gram of different food categories. Comparing calories content instead of food weight, easier allows comparison between different food habits. Based on a master thesis by Stamm (2015), average daily calorie content for a person was compared with the survey of consumer expenditure to estimate the amount of each food group consumed. Various sources were used to find the environmental impact of the different foods, as listed below.

Scientific study	Food category
Hille et al. (2012)	Bread, grain products, cakes, fruit and berries, meat and meat products, butter, margarin, oil.
Agri-food, Blonk (2015)	Sugar, sweets, potatoes, other vegetables, eggs, milk and yoghurt, cream and cream products, cheese
Wallén (2004)	Fish and fish products
Martin (2009)	Juice and mash
Saxe (2010)	Beer, wine, liquor
Humbert et al. (2009)	Coffee

Further, we estimated the climate effect of different food habits, like being a vegetarian or a vegan. More information regarding the inputs and variables are found as descriptions within the climate calculator.

The effect of ecological food and large scale vs. local food production is not implemented in the calculator at current state.

The parameters listed below represent different food habits that the user can choose between in the calculator.

Amount

The amount of food is set as the base for the calculations. This is measured in calories and a Norwegian average of 2700 kcal is set as the daily average calorie intake. This will vary, based on gender and personal food consumption. Note that although the composition of the different diets will vary, the calories amount is set to be constant with all the different diets (vegetarian, vegan, flexitarian etc.).

Meat

Meat consumption has the highest impact per calorie of all the food groups. On average, meat production emits 3 times as much CO_2 emissions per calorie than the production of the average vegetable.

Note that the environmental impact will vary based on what kind of meat you consume, although an average value for meat is chosen in the calculations. Poultry has the lowest environmental impact, while beef and lamb generally have a high impact.

Dairy products

Since dairy products are associated with animal husbandry, they are also associated with high environmental impacts. Specifically, milk, yoghurt and cheese have high emissions per calorie content, comparable to the average meat emissions.

Food waste

Food waste represents an efficiency loss, and thus is associated with an environmental impact. If we reduce food waste at the consumption stage, this food will not have to be produced, and thus we get an emission reduction. Studies show that consumers waste 10-13% of the bought food[1] [2]. We use an average value of 10% food waste in Norwegian households. Since it is unlikely that we will be able to completely reduce our food waste, we estimate that it can be reduced by a maximum of 70%.

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[1] Hamilton, H. a., Peverill, M. S., Müller, D. B., & Brattebo, H. (2015). Assessment of food waste prevention and recycling strategies using a multi-layer systems approach. *Environmental Science & Technology*, (October), acs.est.5b03781. http://doi.org/10.1021/acs.est.5b03781

[2] Stensgård, A. E., & Hanssen, O. J. (2015). *Matsvinn i Norge 2010-2015. Sluttrapport fra ForMat-prosjektet*.

3.2 Energy

Energy sources

The majority of Norwegian electricity is produced by hydropower, which is a renewable energy source. However, Norway is connected to the Nordic electricity grid, and we transmit electricity to other Nordic countries, which in turn trade with other European countries. These countries' electricity production is not based solely on renewables, but also on fossil fuels like coal and gas power plants as well as nuclear energy. Therefore, we use an average emissions from Nordic electricity production when calculating emissions from energy use in households. For the electricity consumed in the households, a factor of 128 g CO_2 eq/kWh was used. This is an average value for the Nordic electricity delivered to households for 2011 - 2015.

Emissions from district heating are a national average from 2011-2015. The average national district heating mix can be found on www.fjernkontrollen.no and is a mix of oil, gas, electricity, bioenergy, heat from waste incineration and free heat from the surroundings (heat pumps etc.). Emissions of biogenic CO_2 have to be taken into consideration here, as they will have an effect on climate change in the short term. Biogenic CO_2 emissions are valued with a factor of 0,43 compared to fossil CO_2 emissions. This gives emissions of 0,227g CO_2/kWh for district heating using processes found in the Ecoinvent database.

Based on user input, it is also possible to calculate the consumption of fuel oil and wood incineration in the home. Fuel oil includes oil combusted in the house or apartment, as well as collectively, for instance in an apartment complex. The CO_2e factor is taken from the Ecoinvent database and is 0,34 kg CO_2e/kWh.

Wood combustion is also included in the calculations. Not only must the direct emissions from wood combustions be included as previously mentioned, but felling, cutting and transportation of logs also has an environmental impact which should be included. The emissions factor with Ecoinvent background processes is 0.221 kg CO_2e/kWh.

There is a potential to reduce energy consumption by using heat pumps. Enova (https://www.enova.no/radgivning/privat/rad-om-produkter-og-losninger/oppvarmingsalternativ/luftluft-varmepumpe-/112/0/) gives an estimate of the yearly energy savings that can be achieved using different types of heat pumps. Depending of which heat pump that is chosen, it can reduce energy usage for heating of housing and water with between 35% and 60%, on between 60% and

85% of the energy use in these two categories. (as long as indoor temperature is not increased of course)

Heating of household

The basis for the calculations is the average energy consumption per m^2 for different dwelling types given by Statistics Norway. The distribution for different heat sources and energy consumption posts (space heating, water heating, etc.) is also given by Statistics Norway for different dwelling types. This is used to give an initial distribution of average energy consumption.

Statistically, energy use in a household will vary based on number of people in the household as well as the house type and the year the house was built in/renovated. Statistics Norway gives energy use per area for different house types and number of persons in the household. This is used to adjust the total energy use for the household with the number of people living in the household. Additionally, Sandberg et al. (2016) give energy use per dwelling type, renovation standard and construction year. The correction for construction/renovation year is based on a subjective evaluation of these numbers.

These calculations give a close estimate for the average energy consumption given the different parameters. It is also possible for the user to override these values if household energy consumption, heat source etc. is known.

Water heating

Water heating is calculated from a bottom-up approach and reconciled with average yearly water heating per household from Statistics Norway, which is 2600 kWh. Average water use is given as 9,5 liters per minute and it takes 0,041 kWh of energy to heat one liter of water from 10-38 ℃. With a water use length of 8,5 minutes per day for 2,2 persons, this gives an average energy consumption of 2659 kWh per year, which coincides with the statistical yearly use. Based on this the water usage is estimated per person in the household, and the users can vary the input to customize the energy use to actual habits.

The calculator takes into account the energy carrier (electricity, heat pump etc.) used to heat your water.

Lighting and Electronics

Among the household energy consumption that is specific to electricity, is energy use for lighting and electronic appliances. According to Statistics Norway, the average energy use for lighting in Norwegian homes is 1000 kWh per year. This consumption can be decreased by conserving energy and installing LED-lights.

Energy consumption for electronics will vary but an average value of 2850 kWh per year is given. As dishwashers and tumble-driers are the two most energy consuming appliances these are evaluated separately, and their consumption will be affected by how often they are used.

The initial data in these categories are calibrated based on the number of people in the household, and divided on household members. Individual habits can further influence the emissions as described in the climate calculator.

3.3 Consumption

Based on Statistics Norway's Survey of Consumer Expenditure, we have average number for how much money 9 different household compositions (e.g 2 adults, and 2 kids) spend on 46 different consumption categories such as housing, clothing etc. These amounts are calibrated with household income, and average amounts for money spent on energy, transport and food are removed as these categories are considered from a bottom-up perspective. Tax have been removed from the income based on general tax tables, as emissions from tax money are covered by the public emissions.

Greenhouse gas emissions from household consumption are based on Steen-Olsen et al. (2016), as a basis for the consumption of household goods and services. By using economic input-output tables, emissions for different consumption categories can be calculated per Norwegian Krone (NOK) spent by a household. Emission factors per NOK are found in Steen-Olsen et al. (2016). Examples are that average spending has an emission of 44g CO_2e per NOK, while spending money on clothing has an average emission of 51g CO_2e per NOK and culture arrangements are normally below 20g CO_2e per NOK

In calculations, it is assumed that all income is spent in some way. If you spend a lot of money on paying down loan or put them into the savings account, it is probable that the money is still used then to build housing etc. And the assumption is therefore probably quite right.
We are still working on concepts for tracking money use on a more monthly basis as the impact from consumption is so essential, and it is interesting to see how this changes over time.

It is assumed that all household income is divided equally on all household members. Functionality for customizing personal monetary spending will be developed.

We have also estimated the effect of a change in consumption habits as described briefly below. Details can be found in the calculator descriptions.

Quality- and repair consumer

The main assumption is that an increase in the lifetime of a product completely replaces the need to buy a similar product in the relevant time frame. As an example, if you use an object 20% longer than its expected lifetime, you save climate change emissions equal to 20% of production emissions of that object.

Ethical consumer

For this habit it is estimated both that the user spends more money on energy, transport and food, and these amount are removed from consumption amounts. In addition, it is assumed that emission per NOK spent in consumption items are less, as it usually cost more to take ethical considerations in all purchases.

Service consumer

As money spent on services such as movies, news, music, theatre etc. has a lower impact than money spent on products a percentage of total consumption as described in the calculator is moved from all product items, and divided on all service categories.

Donations

Reduced money usage is one of the best climate actions. Money donated to others is removed from the consumption category of the users, and the emissions from this money are allocated to the ones receiving the money.

Recycling

Emission savings from recycling are based on the average waste and recycling rate of Norwegian households for paper, glass, plastic and metal waste. The amount of waste per household is taken from statistics Norway, while the current recycling rates are taken from syklus.no and grontpunkt.no. CO_2e reductions per kg recycled for the different materials is taken from loop.no. Emission reductions for paper and plastic are compared to waste incineration, by comparing current recycling rates with an optimal recycling rate which is deemed realistic we see the potential emission reduction from increasing our recycling. Especially plastic, paper and metal have a potential for increased recycling rates.

It is worth noting that in carbon accounting, the person recycling does not get the CO_2 reduction benefit from recycling, rather the person using the recycled material get the benefit. We do however want to encourage recycling as an environmentally positive action in many ways (climate, resource scarcity etc.), and want to highlight the climate effect of recycling. Therefore, it is included in our calculations.

3.4 Transport

All transport emissions are calculated in the way that the user can input travel length and way of transportation for work, leisure and holiday travels. Distances are multiplied by emission factors for different forms of transportation to define the total emission.

Travel lengths

Default travel lengths are found from the Norwegian travel survey from 2013 (Reisevaneundersøkelsen, Statistics Norway). These distances/parameters can be changed by the users.

The following values are set as default travel lengths:

- Length to work is set to 10 km each way
- Leisure travel distance is set to 140km each week
- Long trip travels are set to 1 flight (one way) to Scandinvaia, 2 flights to Europe, 2 Regional trips with public transport and 4 regional trips with car.

Means of transportation

Default means of transportation are also found from the Norwegian travel survey. In addition we change the default values for leisure and work habits based on vehicles in the household. E.g if the household has more vehicles than adults it is assumed that personal vehicles are used every day, while if there are less vehicles in the household the amount of public transport increases up to 7 days a week in four steps.

The downside of this is that the calculations will not include the number of cars owned. If the user is an avid car collector and has ten cars, this will not be reflected in full on user's footprint. This could be improved in the future, but it should not be a large error for the majority of users.

Emission factors

All emission factors are defined as grams of CO_2e per kilometer traveled per person. The numbers include the whole life cycle of the vehicles, both emissions from production and direct emissions from fuel combustion.

The factors are relatively generalized, for the purpose of making the calculator user friendly. In the calculations, the following factors are used for different transportation vehicles:

	g CO2 eq/km	Direct emission	Emissions from production	Source
Fossil fueled car	257	214	43	Ecoinvent europeisk snitt
Electric vehicle	81	included	included	Ecoinvent 3, Electric vehicle with nordic electricity mix
Hybrid car	180	included	included	Samaras 2008, Low Carbon Scenario
Car from car sharing	147	Included, average of above	10% of normal	estimation
Motorbike	108	94	14	Ecoinvent Scooter
Regular bus	103	94	9	Ecoinvent 3 Regular bus
Long distance bus	52	46	6	Ecoinvent 3, Coach
Train	42	See descriptions	See descriptions	Andersen 2007
Boat	803	included	included	Andersen 2007
Short distance flight	340	See descriptions	See descriptions	See descriptions
Medium distance flight	286	See descriptions	See descriptions	See descriptions
Long distance flight	239	See descriptions	See descriptions	See descriptions

Car sharing emissions

For cars from car sharing we have estimated that there are 10 users per car, and that emissions from car production and maintenance are 16% of the car emissions. These emissions are therefore divided by 10 users, hence reduced with 90%. An average emission from all car types are used as a basis for this emission, and then minus 90% of maintenance/production emissions.

Train emission factors

Train: 55 g CO2 /pkm [*Andersen*, 2007] with indirect emissions of 7 grams CO_2-eq per person-km (www.ecoinvent.org).

Metro: 26 g CO2 /pkm [*Andersen*, 2007] with indirect emissions of 15 grams CO_2-eq per person-km (www.ecoinvent.org).

For simplicity a weighted average between these two is used to get 42 g CO2/pkm for rail transport.

Flight emissions factors

- 158 g CO_2 per person-km for domestic flights
- 130,4 g CO_2 per person-km for short international flights (European)
- 105,6 g CO_2 per person-km for long international flights (intercontinental)

Source: (DEFRA, 2008)

These emissions were multiplied by a "height factor" of 1.8 to adjust for the fact that the emissions occur at altitude and have additional climate effects.
Source: Lund et al. (2016)

Indirect emissions must be added to these numbers (www.ecoinvent.org)

- 56 g CO_2 per person-km for domestic flights
- 52 g CO_2 per person-km for short international flights (European)
- 48 g CO_2 per person-km for long international flights (intercontinental)

IMPORTANT: indirect emissions must not be multiplied with height factor, i.e. multiply height factor before adding indirect emissions.

Business travels

Business travels during work hours do not count, as these are (or at least should be) included in the company's carbon footprint.

3.5 Public Emissions

Calculations of emissions from the public sector are based on economic data (similar to the calculations of household consumption emissions). The yearly spending in the public sector is documented in KOSTRA (Local Governments-State-Reporting). This way, all direct and indirect emissions are accounted for. Currently, these emissions are equally divided to all inhabitants in Norway as we all benefit from our public sector. The emissions are divided into municipalities, counties, and national levels.
There is a possibility to expand these emission data to reflect the climate footprint of your local municipality based on where you live.

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