UNIVERSITY OF ICELAND
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Calculation criteria used in the 1.5 Degree Carbon Footprint Survey

This 1.5 Degree carbon footprint survey calculator includes yearly direct greenhouse gas emissions of individual's diet, housing, vehicles, travelling, consumption of goods and services, pets and second homes. The survey is a part of the University of Iceland's research project "1.5 degree compatible living in the Nordic conditions: attitudes, lifestyles and carbon footprints", funded by RANNÍS (Icelandic Centre for Research). The calculation paths behind the survey result webpage are presented in this paper, together with the GHG coefficients.

The carbon footprint is calculated for one year per person. Since the conditions vary between the Nordic countries, some coefficients are country specific (such as electricity, district heating, consumption). Coefficients are defined by the country which the participant has selected in the very beginning of the questionnaire. Both the direct and indirect GHG emissions are included in this carbon footprint calculator.

1. Diet

Greenhouse gas emissions of diet are based on the diagrams presented in the end report of the FoodMin project, published by Finland's Prime Minister's Office (Saarinen et al. 2019), accompanying one additional category for even higher meat consumption (300 g/day). Highest meat consumption has a coefficient value which is derived from the previous diet coefficient values from Saarinen et al. (2019). The values used to calculate the diet emissions are presented in Table 1.

Table 1. Greenhouse gas coefficients used to calculate the yearly climate impact of an individual's diet (Saarinen et al. 2019).

Diet	Kg CO2e/2200kcal/day (Saarinen et al. 2019)	kg CO2e/year
Vegan/vegetarian	3.1	1132
Pescatarian	3.5	1278
Omnivore 50g meat/day	4.2	1533
Omnivore 70g meat/day	4.6	1679
Omnivore 150g meat/day	6.9	2519
Omnivore 300g meat/day	(2519-1132)/2+2519	3213

2. Housing

Information about housing type, decade of construction, heating and electricity sources and size of home are collected in the survey to calculate the climate impact of housing. In households where two heating methods are used, the primary heating method is calculated as 80 % and secondary heating method as 20 % of total heating. In case person's household consists of more than one person, the housing emissions are divided by the size of the household. Household in this context refers to people who live alone or together as a family or family-like circumstances, sharing their living spaces and funds. Roommates are not included.

Personal housing emissions are a sum of heating and electricity, divided by the size of the household. Heating and electricity are calculated as follows:

Household heating emissions with single heating system:

Energy consumption per m^2 * Size of home * kg CO_2e of primary heating type

Household heating emissions with secondary heating system:

Energy consumption per m^2 * Size of home * (0.8 * kg CO_2e of primary heating type + 0.2 * kg CO_2e of secondary heating type)

Energy consumption per m^2 is based on the building's type and decade of construction (Vimpari, J. 2021). Values used are presented in Table 2. Detached house values are utilized in calculations for both detached and semi-detached houses. If a participant selects "Other" as a housing type, apartment values are utilized.

Table 2. Energy consumption per m^2 (MWh/k-m2/year) and the housing type (Vimpari, J. 2021).

	apartment	detached	rowhouse
1950	0.167	0.18	0.182
1960	0.196	0.203	0.2
1970	0.178	0.18	0.181
1980	0.148	0.152	0.151
1990	0.158	0.153	0.151
2000	0.132	0.133	0.134

Greenhouse gas emissions of different types of heating methods are based on CO_2e/MJ per unit of output average values of European countries by Cherubini et al. (2009), which are converted to kg CO_2e/MWh by first converting 1 MJ = 0.000278 MWh. Cherubini et al. (2009) have elaborated the data from the software tool GEMIS ("Global Emission Model for Integrated Systems") Version 4.42 (GEMIS, 2008). GEMIS is a life cycle analysis program, and its calculation of impacts includes the total life cycle of fuel delivery, materials used for construction, waste treatment and transport/auxiliaries. Coefficients cover efficiency, power, capacity factor, lifetime, direct air pollutants, greenhouse gas emissions, solid wastes, liquid pollutants and land use. However, direct or indirect land-use changes are not included.

For calculating the emissions of heat pumps for heating, GHG emissions of electricity (renewable or non-renewable) are multiplied by 0.33 (coefficient of performance 3 for heat pumps).

Calculating district heating

District heating coefficients are calculated by using the heating GHG emissions presented in Cherubini et al. (2009) and the national shares of country's district heating sources: 2 % of district heating for Finland was calculated as oil, 37 % as coal, 11 % as natural gas, 40 % as biomass and 10 % as secondary heat of industry, based on statistics Finland (2019b) with slight modifications (other fossil [4%] and peat [15%] are included in coal class and other renewables [5%] and black liquor [1%] in biomass class, other energy sources [10%] were calculated as secondary heat of industry [0 kg CO2e]).

For Iceland, district heating was calculated as 100 % geothermal heat (Karlsdottir et al. 2020).

District heating for Denmark consists of biomass (59%), solar energy (2%), natural gas (19%), non-renewable waste (calculated as oil 9%) coal (11%) and oil (1%) (Euroheat & Power 2019). Biogas, geothermal energy and heat pumps are integrated to the biomass class (together 1-2%).

Sweden's district heating shares are 25% from waste to energy (calculated as 50% plastic [oil] and 50% bio [0kg CO2e]), 41% biomass, 2% biogas from bio waste (calculated as 0), 7% heat pumps (electricity * 0,33), 3% electricity, 2% coal and peat (calculated as coal) and 19% secondary heat from industries and flue gas condensation (0 emissions) (Energi Företagen 2020).

For Norway, the district heating shares are 48% from waste to energy, 5% from waste heat, 11% from heat pumps, 21% from biomass, 12 % from electricity and 3% from natural gas (Norsk fjernvarme 2020). Waste to energy is calculated as 50% of plastic (oil) and 50% of bio (0kg CO2e). Waste heat is calculated as 0kg CO2e. Electricity is calculated as 100% hydro electricity and heat pumps have the electricity coefficient * 0,33 (coefficient of performance 3).

Coefficients for different heat sources are from Cherubini et al (2009) and they are all presented in Table 3, together with the district heating coefficients.

Table 3. Greenhouse gas coefficients used to calculate the personal share of emissions of different heating methods (average values for heat sources from Cherubini et al. 2009).

	kg CO2e/MWh
District heating Finland	229
District heating (geothermal) Iceland	11
District heating Denmark	168
District heating Sweden	79
District heating Norway	111
Oil	378
Coal	468
Natural gas	279
Geothermal	11

Heat storing fireplace	45
Fossil oil boiler	378
Bio oil or firewood/pellets boiler	45
Solar panel heating/ Solar thermal heating	72
Heat pumps	Electricity * 0.33

Calculating electricity

Greenhouse gas emissions for electricity are calculated as follows:

Electricity demand * Size of home * kg CO2e of electricity

Electricity demand has a standard value of 0.03 MWh/m²/year which is calculated by dividing the electricity consumption of a standard equipment household per capita 1400 KWh/year (Adato Energia 2013) by an average floor area per person in Finland, 41 m² (Statistics Finland 2019a).

The coefficients for electricity are based on the country's electricity mix and Cherubini et al. (2009) average GHG emissions for electricity and cogeneration by source. For coal, the minimum value from Cherubini et al. (2009) was used instead of average value, to better take into account the large shares of cogeneration in Finland, Sweden and Denmark. In the cases of Finland, Sweden, Norway and Denmark, the survey gives an option to choose renewable electricity. If renewable electricity is selected, the country electricity mix coefficient is replaced with a renewable electricity coefficient consisting of 25% biomass, 25% wind, 25% hydro and 25% solar power. All the electricity coefficients are presented in Table 4.

Electricity mix for Finland consists of 18% hydro, 9% wind, solar 0.3%, biomass 18%, waste 1%, nuclear 35%, coal 8%, oil 0.3%, natural gas 6% and peat 4% (Finnish Energy 2019). Peat has the same coefficient value as coal and waste is calculated as 50% of plastic (oil) and 50% of bio (coefficient value 0).

For Iceland, 71% of the electricity mix was calculated as hydro and 29% as geothermal (Orkustofnun 2015).

Denmark's electricity mix consists of coal (12%), natural gas (7%), oil (1%), wind (56%), solar (3%) and 21% of biomass (Danish Energy Agency 2019).

Electricity mix for Sweden: 38.7% hydro, 11.8 % wind, 0.4% solar, 5% biomass, 3% waste, 39.5% nuclear, 0.2% coal, 0.4% natural gas and 1% coal (International Energy Agency 2019). Waste is calculated as 50% of plastic (oil) and 50% of bio (coefficient value 0).

For Norway, electricity mix is dominated by hydro power (92%) and the rest consists of geothermal (2%) and wind 6% (Statistics Norway 2020).

Table 4. Greenhouse gas coefficients used to calculate the personal share of emissions of electricity (average values for electricity and cogeneration from Cherubini et al. 2009 [minimum value for coal]).

Electricity Finland	209
Electricity Iceland	19
Electricity Denmark	199
Electricity Sweden	67
Electricity (hydro) Norway	18
Renewable electricity	54
Hydro	18
Wind	20
Solar PV	99
Biomass	81
Geothermal	22
Coal	1079
Oil	899
Nuclear	63
Natural gas	540

3. Vehicle Possession

Personal vehicle emissions are a sum of the direct driving emissions driven by each possessed vehicle, divided by the size of the household. Yearly driven kilometers, type of fuel and fuel consumption of the vehicle are needed to calculate the greenhouse gas emissions of a single vehicle. Option to sometimes use also another fuel is included in the survey, in which case the secondary fuel covers 5%, 15%, 25%, 35% or 45% of total fuel emissions.

Greenhouse gas emissions of different fuels are presented as g CO2e/km in Cherubini et al. (2009), with consumption of 2.45 MJ/km. Therefore, the values are converted from MJ to liter for liquid fuels and from MJ to m^3 and kg for gas fuels. The converted greenhouse gas emissions of different fuels used in this calculator are presented in Table 5.

Table 5. Greenhouse gas coefficients used to calculate the personal share of yearly driving emissions and conversion values. (Cherubini et al. 2009).

	MJ to liter	MJ to kg	Coefficient	Unit
Gasoline	34.2		3.003	kg CO2e/liter
Bioethanol (sugar cane and other	23.4		1.003	kg CO2e/liter

crops)				
Diesel	38.6		3.189	kg CO2e/liter
Biodiesel (rapeseed, soy, sunflower)	38.6		1.732	kg CO2e/liter
Natural gas		39MJ/m3 0.72kg/m3	3.761	kg CO2e/kg
Biogas		39MJ/m3 0.72kg/m3	1.382	kg CO2e/kg

Vehicle emissions:

Yearly driven kilometers * Fuel consumption * Kg CO2e of selected fuel

Electric vehicles are calculated by multiplying yearly driven kilometers by vehicle's electricity consumption (0.0125 MWh/100km) and greenhouse gas emissions of electricity (Table 4).

CO2 emissions from production of a new vehicle are not included in the calculations. In the suggestions, the production emissions of a new vehicle are said to be around 10 t CO2e. This is based to Dillman et al (2021) paper, in which the production emissions of a PHEV and HEV are 9,56 t CO2e and a BEV is 11,3 t CO2e.

4. Local Travel

To calculate the emissions of public transportation, an average value of direct greenhouse gas emissions of natural gas bus, commuter train, tram and metro were utilized based on the data from VTT Technical Research Centre of Finland (2021). The indirect greenhouse gas emissions from vehicles, infrastructure, fuel production and supply chain (Chester & Horvath 2009) were added to all transport modes before calculating the average public transportation coefficient, 0.12 kg CO2e/PKT, used in the calculator.

In the survey, participants were asked to estimate how many kilometers did they travel by public transportation, and this was multiplied by 0.12 kg CO2e to get the GHG emission of local travel.

5. Leisure Travel

Production emissions of vehicles, infrastructure, fuel production, and supply chain emissions are added to all transport modes included in leisure travel section (airplane, ferry, train, bus) according to Chester & Horvath (2009). Direct emissions are calculated based on the travel distance and transport mode. Exact values used to calculate the travel emissions are presented in Table 6.

For short distant leisure travel, boat trips are calculated as 250km * 2 (return). Airplane, train and bus are calculated as 500km * 2 (return).

For medium distance leisure travel, boat trips are calculated as 1140km * 2 (e.g. Helsinki to Travemunde and back). Airplane, train and bus are calculated as 2000km * 2 (return).

For long distance leisure travel, boat trips are calculated as 6000km * 2 (e.g. Southampton to New York and back). Airplane, train and bus are calculated as 8000km * 2 (return).

Table 6. Greenhouse gas coefficients used to calculate the emissions of leisure travel. (Aamaas et al. 2013; Chester & Horvath 2009; VTT Technical Research Centre of Finland 2021).

	kg CO2e/km/person
Flights <800km	0.34
Flights >800km	0.28
Ferry	0.36
Train (Pendolino & Intercity)	0.08
Long Distance Bus (18/50 passengers)	0.15

6. Goods & Services

The greenhouse gas emissions resulting from the consumption of goods and services are defined by utilizing ENVIMAT -model (Alhola et al. 2019). Classification of Individual Consumption According to Purpose (COICOP) consumption categories are utilized both in the survey and in ENVIMAT -model (United Nations 2018). Inflation corrections are added to ENVIMAT 2016 intensities according to Statistic Finland (2020), updating the intensities to 2020. Currency exchange rates (EUR/EUR=1) are from the same year, 2020, as follows: SEK/EUR=10.4865; NOK/EUR=10.7238; ISK/EUR=154.59; DKK/EUR=7.4543 (European Central Bank, 2021).

Personal emissions are calculated by multiplying the used amount of money by the category coefficient. Coefficients for different categories are presented in Table 7.

Table 7. ENVIMAT -model based greenhouse gas emission per currency for different consumption categories (Alhola et al. 2019).

	kg CO2e/EUR	kg CO2e/ISK	kg CO2e/SEK	kg CO2e/NOK	kg CO2e/DKK
Alcohol & Cigarettes	0.17	0.0012	0.017	0.017	0.024
Clothing & Footwear	0.32	0.0021	0.031	0.031	0.044
Interior Design & Housekeeping	0.47	0.0031	0.046	0.045	0.064
Health	0.16	0.0011	0.016	0.016	0.023
Recreation & Culture	0.36	0.0024	0.035	0.035	0.050
Restaurants	0.3	0.0020	0.030	0.029	0.042

Hotels	0.4	0.0027	0.039	0.038	0.055
Electronics	0.6	0.0040	0.059	0.058	0.083
Other goods & services	0.19	0.0013	0.019	0.019	0.027

The slider default values on the questionnaire's Goods & Services consumption category questions are from Alhola et al. (2019) and they are based on the annual average personal consumption of Finnish consumers.

7. Pets

Yearly greenhouse gas emissions for a dog are 630 kg CO2e (Yavor et al. 2020). Emissions of a dog were divided by two to get the emissions of a cat, 315 kg CO2e (Herrera-Camacho et al. 2017). Other unknown pets had zero emissions.

8. Second Homes

Greenhouse gas emissions for second homes are based on a carbon footprint model of Finnish consumers (Ottelin et al. 2015), being 884 kg CO2e/year divided by the size of the household.

9. Other information

The income classes in "Your personal income" -question are based on income deciles (EuroStat 2018) with one additional class which has the value of the 9th decile plus 9th decile / 2. The values are converted to local currencies as follows (2018 average rates): EUR/EUR=1; ISK/EUR=137; DKK/EUR=7.45; NOK/EUR=9.6; SEK/EUR=10.26 (yearly average currency exchange rates for 2018) and rounded to the nearest 5 euros.

On the compare your results to others part, the World average 3.4 t CO2e is a personal consumption carbon footprint per year (Ivanova et al. 2016).

10. Suggestions for action

Suggestions shown in the end of the survey, under the carbon footprint, are common for all the survey countries (Finland, Iceland, Sweden, Norway, and Denmark). The example values are calculated by using the coefficients for Finland, presented in this document. Since the conditions vary between these countries, some values shown in the suggestions are only indicative and are not going to be utilized in any future research.

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