CLIMATE CAMPAIGNERS

Report on Target lifestyles

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Disclaimer

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1. Executive Summary

Individuals and households account for more than two-thirds of global greenhouse gas (GHG) emissions (Ivanova et al., 2020). Although their carbon footprint derives largely from energy consumption (such as fuel for transport, electricity, heating), agricultural practices (such as cattle breeding, rice cultivation) also contribute to a significant proportion.

European households' average GHG emissions amount to 7.5 tons of carbon dioxide equivalents (tCO_2e) per capita. Steep reductions of this level are required to decrease to a global average lifestyle carbon footprint of 2.5 tCO_2e/cap by 2030 to comply with the objectives of the Paris Agreement (Capstick et al. 2020). The challenge is enormous and relies partially on citizens' choices on all the aspects of their lifestyle (such as transport, diet, housing, consumption of manufactured products and services).

This Deliverable 1.3 report of the CAMPAIGNers project aims to describe carbon-neutral lifestyle targets for citizens and identify changes in household consumption patterns to low-carbon alternatives, such as transport model shifts, home energy reduction and dietary shifts that present the most significant mitigation potential. The report must serve as a critical input to WP 3 of the project when designing and developing candidate LifestyleChallenges.

The first part of this report briefly analyses the electricity mix of the different countries involved in the project, a key element to effectively identify behavioural changes that need to be targeted as priorities, and the alternatives to the current lifestyle that should be encouraged.

The second part reviews the main options for lifestyle changes in the transport, food, housing and other consumer sectors, assessing the impact of these changes on the carbon footprint of households. The purpose of such analyses is to identify the targeted lifestyle changes that are the most impactful, also considering the potential co-benefits.

Studies assessing the household footprint mitigation potential of specific lifestyle changes show that car and plane mobility, meat and dairy consumption, and heating are the most dominant components of EU household footprints, with, however, significant differences across regions (depending on the local electricity mix and the type of climate) and socio-economic categories. As a result, LifestyleChallenges should primarily target lifestyle changes that promote large-scale reductions in motorised transport, shifts towards plant-based diets, and energy-efficient housing while taking into account carbon inequality in the EU and across regions and social groups.

A reduction in car and air travel through a shift toward less carbon-intensive modes of transportation (such as public transport, bike) are standard lifestyle change options incorporated in modelling studies and are clearly identified as priorities. There is also substantial mitigation potential to reduce emissions from mobility by avoiding or curtailing air travel, although this mainly concerns the wealthiest households who fly. All lifestyle change options in the domain of transport offer essential co-benefits.

Food is a significant source of household emissions, contributing to about 30% of EU household carbon footprint. Food footprint is dominated by red meat and dairy, as animal-based foods are much more resource-intensive and environmentally impactful to produce than plant-based foods (Ranganathan, J. et al. 2016). Studies unanimously suggest that adopting a vegetarian or a vegan diet is the best way to reduce individuals' carbon footprint. Although less critical, simply switching to less carbon-intensive meat (chicken or pork instead of red meat) can lead to an appreciableappreciably impact.

The household carbon footprint for housing comes from the energy used for heating (with variation among locations) and from the electricity used for lighting, hot water, appliances, air-conditioning, and BEV charging, in addition to others. The mitigation options with the highest potential include purchasing renewable electricity, producing renewable electricity, and refurbishment and renovation. These options, which are unrelated to lifestyle, sometimes involve significant investment capacity. They concern lifetime decisions rather than everyday behaviours. However, LifestyleChallenges should be designed to target these specific moments of a household's life when critical decisions impacting the carbon footprint are made.

The last part of the report proposes a classification of the leading lifestyle change options considering the type of civic engagement expected, the possible costs needed to accomplish these changes, and the income inequalities between citizens, which are strongly correlated with everyone's carbon footprints.

The distribution of household carbon footprints is vastly unequal within and across countries. The households with the highest carbon footprint are by and large the households with the highest levels of income. The main reason is their land and air transport contributions to the footprint, which are disproportionally large. Transport is the most vital driver of the carbon footprint of the rich.

Not all lifestyle changes involve the same active effort in changing the nature of consumption or the amount of consumption. The available options to reduce lifestyle emissions can be divided into three categories: Avoid (drastically reducing or avoiding certain behaviours or lifestyles), shift (a substitution *between* categories of consumption) and improve (a substitution *within* a specific category of consumption through improving efficiency or replacing technologies with lower-carbon ones).

These options suggest two scenarios: moving toward a sufficiency lifestyle (implying net reductions in consumption); or opting for green consumption (implying consuming more eco-efficient alternatives), which often implies a higher cost than current lifestyles. Sufficiency options are generally more efficient to reach carbon neutrality, help save money and are usually associated with higher co-benefits. However, they are usually not as popular as green consumption options because they conflict with prevailing economic growth paradigms. In addition, sufficiency options have overall higher mitigation potential in transport, services and clothing, while green consumption options show more impact in food and manufactured products.

Household carbon footprints are partly related to crucial strategic moments such as deciding where to live, having a child, buying (or not) a car, and building a house. The consequences of these decisions on the household carbon footprint can be significant and permanent. This underscores the necessity of targeting those specific events, especially as demographic attributes (household size, ownership status) are more significant than the geographic location in determining households' preferences for lifestyle changes towards a carbon-neutral lifestyle.

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2. Introduction

2.1 Overview

Individuals and households account for more than two-thirds of global greenhouse gas (GHG) emissions (Ivanova et al., 2020). This is because they are the final recipients of most goods and services produced globally.

Their carbon footprint includes all the GHG emissions resulting from every stage of a product or service's lifetime or lifecycle, including direct and indirect emissions. Direct GHG emissions occur during the use phase of products (such as driving a car, heating homes). Indirect emissions refer to emissions generated during the product's manufacturing (including the emissions from the material production) and those generated at their end-of-life (such as recycling, disposal).

In a broad sense, the carbon footprint of households is not limited only to energy consumption. However, direct emissions derive primarily from energy consumption, including fuel for transport, electricity and heating. Huge differences may occur between households' energy consumption and their carbon footprints, depending on lifestyle and local environment, infrastructures and opportunities.

Although the trend towards electrification of cars has accelerated over the last couple of years (in Sweden, nearly 50% of car sales in 2021 were Battery Electric Vehicles (BEV) or Plug-in Hybrid Electric Vehicles (PHEV), 26% in Germany, and 11% in France)[1]theThe vast majority of the cars, trucks and buses currently on the roads still run on petrol and therefore emit CO_2. Furthermore, planes rely exclusively on oil-based fuels. Therefore, driving a car and taking a plane directly and profoundly impacts most European citizens' carbon footprint.

The carbon footprint of households from electricity varies significantly from one household to another depending on where they live, as each country has a different electricity mix and produces electricity differently. Whether the electricity is produced from carbon-based sources (coal, oil or natural gas) or low-carbon sources (renewables (hydroelectricity, wind, solar) or nuclear) directly impacts the households' carbon footprint, although it is largely beyond their means of action.

The third essential sector of household energy consumption, heating, has a very contrasting carbon footprint depending, not surprisingly, on the local climate and the size of the dwellings, but also, within the same area, on the household lifestyle habits and housing conditions. As a result, different solutions for heating exist, some being highly carbon-intensive (such as fuel, gas) while others are not (such as electric heat pump, thermal renovation, passive house) even if they usually carry additional costs.

Beyond energy consumption, a large part of the household's emissions is indirect, i.e. embodied in consumer products and services, including abroad. Considering the complexity of the entire global production chain without omitting or double counting indirect emissions is key to identifying effective lifestyle changes with a higher mitigation potential on global GHG emissions. Europe is a net importer of products and services, hence their embodied emissions. About half of its footprint results in GHG emissions emitted abroad alongside the global supply-chains.

The carbon footprint has not been reduced to carbon dioxide (CO_2) emissions, as other GHG need to be considered. Although CO_2 is the most

[1] Figures are compiled by Clean Technica, based on official registration data in each country (cleantechnica.com).

common GHG, other GHGs may also be emitted, such as methane (CH_4) and nitrous oxide (N_2O), both highly contributing to the agriculture sector's carbon footprint. While CO_2 is typically emitted when burning fuels (oil, natural gas, coal, wood and others), methane emissions primarily result from agricultural practices (cattle breeding, rice cultivation) and natural gas leakages. Household diet thus contributes to their carbon footprint, sometimes to a significant proportion.

Each GHG traps heat in the atmosphere to a different extent, and it stays in the atmosphere for a different duration. These differences make it possible to calculate the global warming potential (GWP) of each gas, making each GHG convertible to the equivalent amounts of CO_2, resulting in a carbon footprint in tons (t) of carbon dioxide equivalents (CO_2e). For example, methane is said to have a GWP 25 times higher than CO_2, while the GWP of nitrous oxide is 300 times higher than CO_2 (considering 100 years). Except when especially mentioned, all the analyses of this report consider all GHG and are therefore expressed in CO_2e.

Global average GHG emissions amounted to 6.3 tCO_2e per capita in 2011; however, these are highly unequally distributed across income groups and countries. The average per capita carbon footprint of North America amounts to 13.4 tCO_2e/cap, while that of India and Africa was at 1.7 tCO_2e/cap on average. Europe fell between the two, with an average carbon footprint of 7.5 tCO_2e/cap (Ivanova et al., 2020).

Steep reductions of these levels are required. According to the Intergovernmental Panel on Climate Change (IPCC), for a population of 8.5 billion by 2030, consumption emissions per capita will need to decrease to a global average lifestyle carbon footprint of 2.5 tCO_2e/cap or less by 2030, and 0.7 tons by 2050, in order to comply with a pathway of limiting climate change to 1.5 ◦C of global warming as decided in the 2015 Paris Agreement on climate (Masson-Delmotte et al., 2018). The carbon allowances to meet the climate targets by 2050 are as low as 0.4 tCO_2e/cap to food, 0.2 to shelter, 0.7 to travel, and 0.8 for goods and services.

The challenge is enormous and relies partially on citizens' lifestyle choices. For example, households are responsible for about 70% of global greenhouse gas emissions, considering all the aspects of their lifestyle (such as transport, diet, housing, consumption of manufactured products and services) through their consumption behaviour.

Only about 5% of the EU households conform to climate targets, with carbon footprints below 2.5 tCO_2e/cap. With an average carbon footprint in Europe of 7.5 tCO_2e/cap, there is a need to reduce the GHG intensity of consumption by a factor of 3 to meet climate targets and adopt sustainable lifestyles, defined as “living well within “the limits of our planet” (European Commission, 2013).

2.2 Aim of the report

Understanding the distribution of lifestyle emissions among populations and activities is essential for efficient and equitable targeting of mitigation measures. When planning mitigation policies or measures, it is crucial to encourage reductions from households with the highest emissions and avoid regressive impacts of imposing burdens on the poor.

Identifying environmentally sound and socially accepted lifestyles is vital for current mitigation and adaptation challenges. For instance, households of the global top 10 per cent of income earners are responsible for using nearly half of all energy for road transport and three-quarters of all energy for aviation, compared with 10 percent and 5 percent, respectively, for the poorest 50 percent of households (Capstick et al, 2021). It is essential to consider these consumption inequities and identify populations with very high and shallow carbon footprints when designing equitable low-carbon target lifestyles.

The aim of this Deliverable 1.3 report of the CAMPAIGNers project is precise to describe carbon-neutral lifestyle targets for groups of citizens and to identify changes in household consumption and behaviour patterns that could lead to carbon-neutral alternatives, such as transport model shifts, home energy reduction and dietary shifts, that present the most significant mitigation potential.

The report must serve as a critical input to WP 3 of the project designing and developing candidate LifestyleChallenges, by identifying and evaluating the mitigation potential of different household lifestyle options within mobility, housing and food sectors, considering all GHG emissions along the whole lifecycle.

The report also distinguishes the most potential options and allows decarbonisation without betting on controversial technologies from seemingly fruitless or present backfire risks.

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2.3 Methodology

In order to produce this report, we conducted a comprehensive literature review of academic publications on household lifestyle environmental impacts, relying on the work of Tasks 1.1 and 1.2. The purpose was to identify and classify original lifestyle options according to their positive mitigation potential. In addition, the review allowed us to summarise and compare the reported GHG ranges of key lifestyle change options and critically appraise results to define target lifestyle challenges.

The issues related to household environmental impacts are primarily covered by various academic studies, applying various perspectives and methods to assess the resource use and wastes associated with consumption. Modelling studies usually assess the potential impact of different mitigation scenarios involving specific behaviour and lifestyle changes on transport, diet, and energy consumption. However, the studies differ in assessment method and methodological choices, system boundary, and modelling assumptions that make them difficult to compare (Dimitru *et al.*, 2017; Girod *et al.*, 2014; Godar *et al.*, 2015 ; Hallström *et al.*, 2015; Moran *et al.*, 2018; Nässén *et al.*, 2015; Suh *et al.*, 2004).

A few recent modelling studies have compiled available data by harmonising the definitions and criteria of the different scenarios. The studies carried out by Ivanova *et al (2020)*, inIn particular, are especially valuable and helpful.

It is, however, essential to remain aware of the limits of the exercise. All models use averages and rarely capture the disparities that can exist between the different regions within a country or the different categories of the population: everyone within the same city and the same socio-economic category does not live in the same conditions of comfort at home, drives their car on the exact distances, travels by plane with the same frequency, or eats red meat in the same quantity.

Inevitably, the models are so made that they always incorporate biases and hypotheses, which are by nature reductive, and do not necessarily correspond with the specific situation of each city. Moreover, rare are studies to consider feedback effects in the global supply chains (e.g. the broader adoption of BEV is expected to reduce oil demand, hence the emissions resulting from its production) and generally disregard embodied emissions in the new infrastructure needed for the low-carbon practices, e.g. the infrastructure of renewables.

The figures reported here should be viewed with caution and understood as general indicators for all these reasons. These are general European averages, but the real impact of each lifestyle change on GHG emissions will always be specific to each household, depending on the specific conditions of each city, including the electricity mix of the local grid.

This report also greatly benefited from the data collected by ICLEI through the series of interviews that were conducted with the LCs. These interviews allowed us to identify their priorities and objectives and better consider the socio-economic context in which the LifestyleChallenges will be disseminated.

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2.4 Outline of the report

The report is organised into three main parts.

The first part briefly analyses the electricity mix of the different countries involved in the project. As explained above, the electricity available to households and individuals is essential for their carbon footprint. This information is key to effectively identifying behaviour changes that need to be targeted as priorities and the alternatives to the current lifestyle that should be encouraged.

The second part reviews the main options for lifestyle changes in the transport, food, housing and other consumer sectors, assessing the impact of these changes on the carbon footprint of households. The purpose of such analyses is to identify the targeted lifestyle changes that are the most impactful, also considering the potential co-benefits of the different options.

The third part proposes a classification of the leading lifestyle change options considering the type of civic engagement expected and the possible costs needed to accomplish these changes. It also discusses the income inequalities between citizens, strongly correlated with everyone's carbon footprints.

These analyses aim to ultimately describe the most efficient carbon-neutral lifestyle for the different categories of citizens, given the associated potential co-benefits and the necessity to avoid adverse consequences, especially for the most vulnerable citizens.

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3. Electricity Mix

The electricity mix represents how electricity is produced in a country. Its carbon intensity depends on the energy sources used to produce the electricity injected into the grid that supplies consumers.

When electricity is produced from thermal power stations using coal, fuel oil or natural gas, it induces significant GHG emissions. For each kWh generated, coal releases 1 kilogram (kg) of CO_2, petroleum releases 0.86 kg of CO_2, and natural gas releases 0.4 kg.

On the contrary, when electricity is produced from solar panels, wind turbines, hydroelectric dams, or nuclear power plants, no CO_2 is released. On the other hand, though, emissions are released during upstream production activities (e.g., solar cells manufacturing, nuclear fuels, cement production, submersion of land during the construction of a dam) and must be considered in their footprint.

The electricity mix largely determines the carbon footprint of each country's electricity production and, therefore, the potential impact of lifestyle changes that lead to a reduction or an increase in electricity consumption.

Switching from a petrol or diesel car to a battery electric vehicle (BEV) will not save much on GHG emissions if the electricity used in the electric car is carbon-intensive. On the contrary, if the electricity is low-carbon, switching from a petrol or diesel car to a BEV will significantly impact the household's GHG emissions. In that case, however, targeting small electricity savings (by unplugging the appliances on standby) does not change much in the mitigation of GHG emissions.

In Austria, Finland, France, Sweden and Quebec, electricity is mostly, if not exclusively, produced from carbon-free sources.

In Turkey, Azerbaijan and South Africa, on the other hand, electricity generation relies heavily on fossil fuels and therefore remains a major emitter of CO_2.

Data source for the series of figures to follow: International Energy Agency (IEA), except for Quebec: HydroQuebec.

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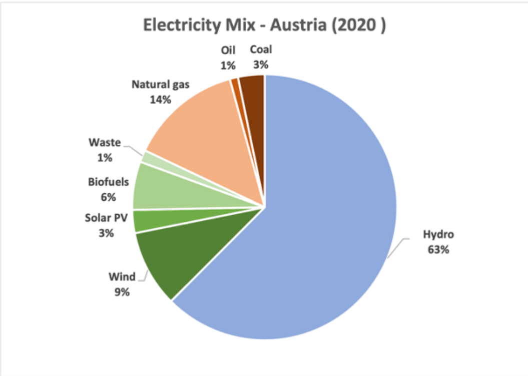
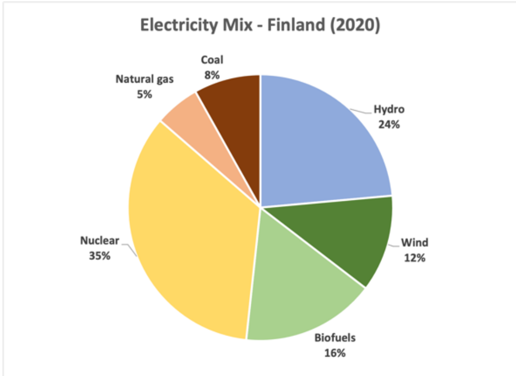
Austria



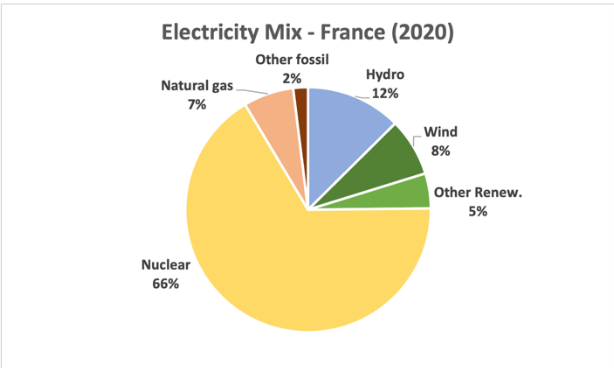
Finland



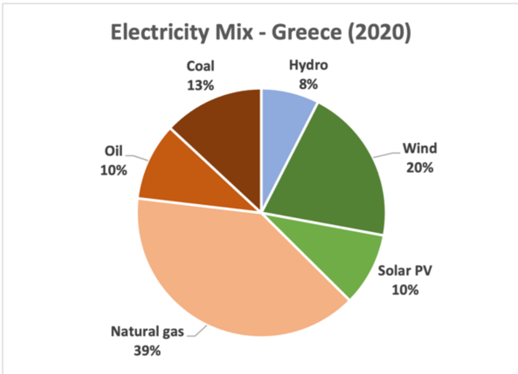
The Austrian electricity mix is largely dominated by hydropower (63%) and other renewable sources (such as wind, biofuels). As a result, the Austrian electricity is low carbon at more than 80%.

More than 85% of the electricity produced in Finland is low carbon, with renewable energy (including hydro, wind and biofuels) representing about half of the production and nuclear accounting for 35%.

France



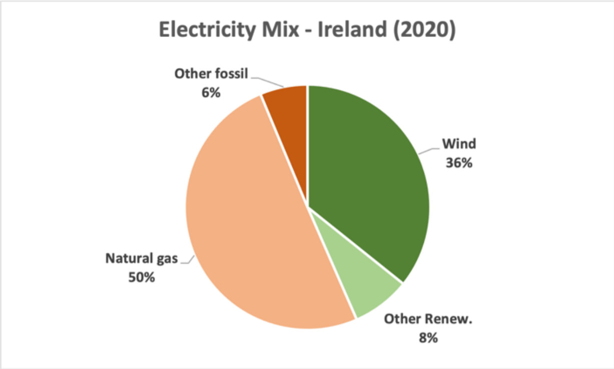
Greece



With nuclear power representing two-thirds of the production and renewables about a quarter, France's electricity mix is 90% carbon-free.

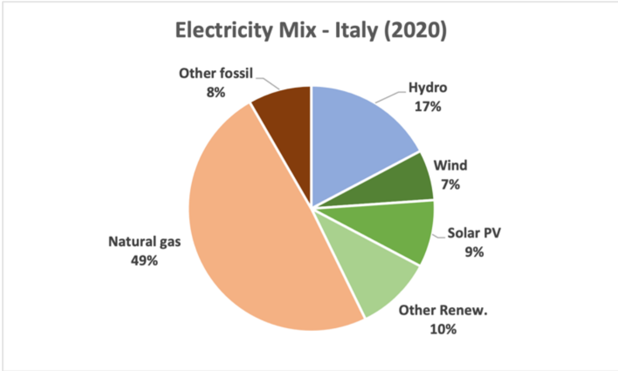
Despite the growing share of wind and solar (30% in 2020, against 5% in 2010), fossil fuels still dominate the energy mix. The share of coal is decreasing rapidly (50% in 2010) but is partially replaced by natural gas.

Ireland



In Ireland, the electricity mix is nearly equally divided between renewable energies (mainly wind power) and fossil energies (mainly natural gas). Wind production is growing fast and has been multiplied by 4 since 2010. Ireland is one of the European countries where electricity consumption is growing the fastest (+15% between 2015 and 2020).

Italy



Italy's electricity mix continues to be dominated by fossil fuels, especially natural gas. The growth of renewable energies is relatively slow (only +9% increase in solar production between 2015 and 2020).

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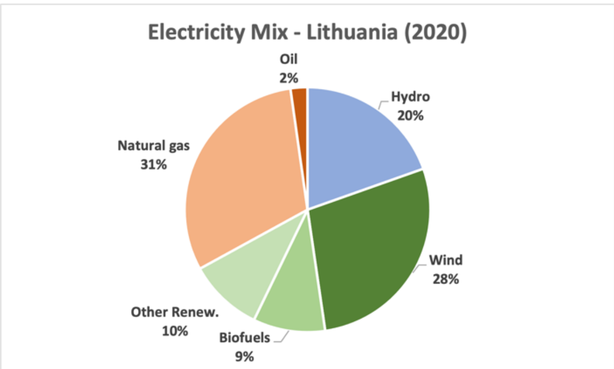
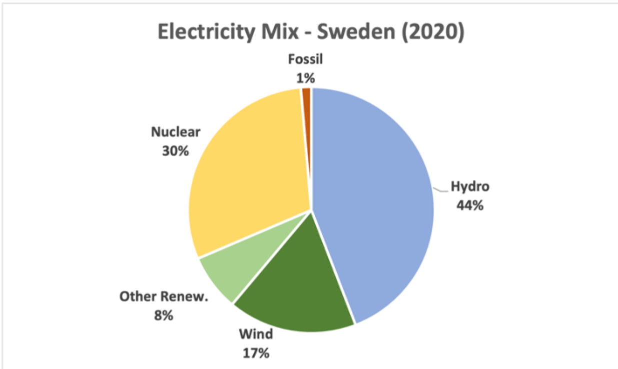
Lithuania



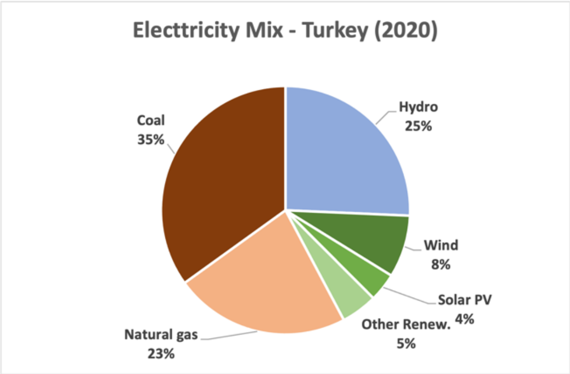
Lithuania closed its last nuclear reactor, generating 70% of its electricity, at the end of 2009. As a result, today, Lithuania's electricity is 66% carbon-free.

Sweden



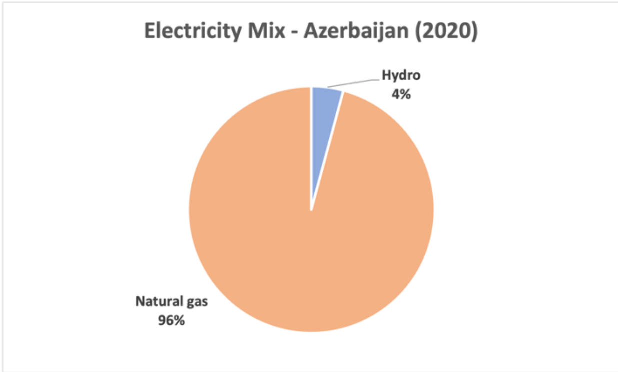
Swedish electricity is 99% carbon-free.

Turkey



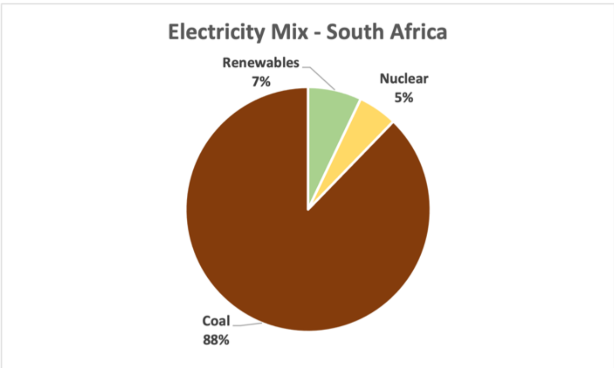
Turkey's electricity mix is dominated by fossil fuels, particularly coal, increasing its market share since 2010. Renewable energy production is nevertheless also growing fast.

Azerbaijan



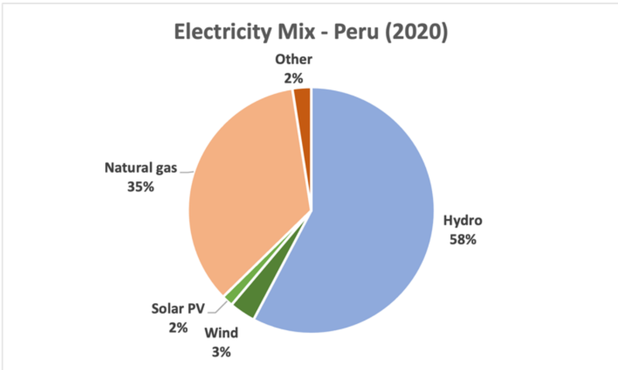
Natural gas makes up more than 95% of the electricity mix in Azerbaijan.

South Africa



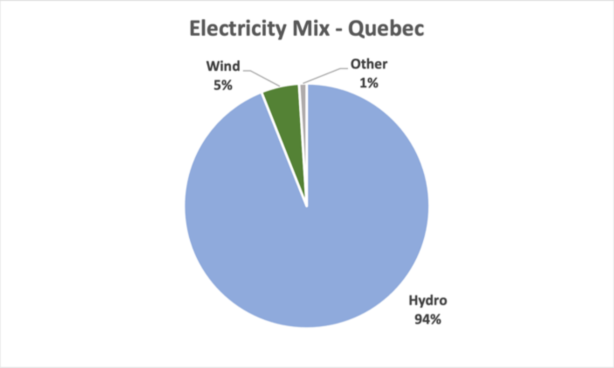
The electricity produced in South Africa is exceptionally carbon-intensive, as coal outrageously dominates the mix.

Peru



Nearly two-thirds of Peru's electricity is low carbon.

Quebec (Canada)



The electricity produced in Quebec is virtually carbon-free.

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4. Household Carbon Footprint

4.1 Overview

More than "two-thirds of global GHG emissions, and 50% to 80% of the land, water and material use, can be directly and indirectly linked to household consumption" (Ivanova et al., 2020).

In all studies assessing the household footprint mitigation potential of specific lifestyle changes, the results show that car and plane mobility, meat and dairy consumption, and heating are the most dominant components of household footprints (Cherry *et al.*, 2018; Duarte *et al.*, 2016; Ivanova *et al.*, 2016; Lacroix, 2018; Schanes *et al.*, 2016). The HOPE (HOusehold Preferences for reducing greenhouse gas emissions in four European high-income countries) project, investigating the preferences of households across several Western European cities, also showed that "household living situations (demographics, size of home, diet) significantly influence the household potential to reduce their footprint, even more than their residence location" (Dubois et al, 2019).

Average household carbon footprint in the EU (tCO_2e/cap)

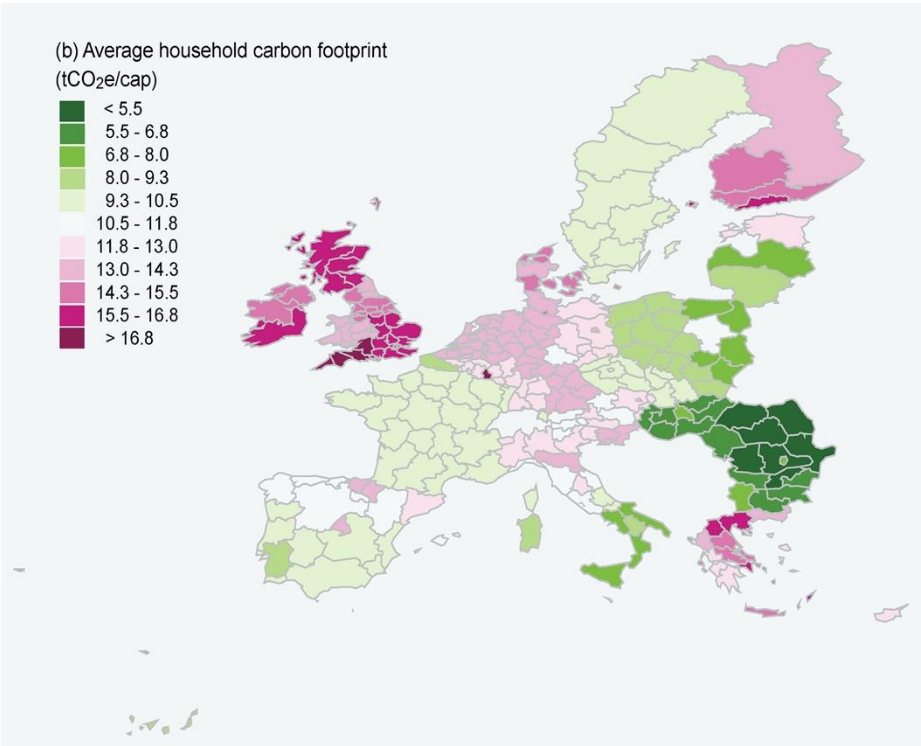


Figure 1: Per capita household carbon footprint across NUTS 2 regions in tCO_2e/cap.

National averages of consumption used for Sweden and the Netherlands

Source: Ivanova, Diana et al. (2017), "Mapping the Carbon Footprint of EU Regions", *Environmental Research Letters*, 12 (054013)

The mobility sector appears to be the most significant contributor to the median European household's footprint (about a third of the carbon footprint, with importance across regions varying between 15%–45%), with most impacts coming from fuel burning. It is followed by food (30%) and housing (20%) (Ivanova et al, 2017). The household carbon footprint for housing is, on average, evenly split between heating and electricity (both accounting for 10% of the household carbon footprint), with significant differences across regions depending on the local electricity mix and the type of climate. The overall literature confirms these relative shares of mobility, food, and housing footprints(Marcotullio *et al.*, 2014; Sommer and Kratena, 2016); Dubois *et al.*, 2019).

The carbon footprint that is attributed to food is derived from two primary sources: (1) indirect GHG emissions linked to the agricultural production process and (2) food transportation. The primary source of GHG emitted by the agricultural sector is the methane generated by the ruminant digestive process (known as "enteric fermentation") and by the livestock manure, as well as nitrous oxide, essentially linked to the nitrogen cycle in the agro-system (nitrogen from fertilisers and livestock manure, ammonia emissions by livestock). carbonCarbon dioxide, mainly from the deforestation and conversion of grassland into pastureland and from the combustion of fuel oil for tractors and heating greenhouses, represents only a minor part of GHG emissions of the agricultural sector.

Distribution of carbon footprints per capita, EU countries (tCO_2e/cap)

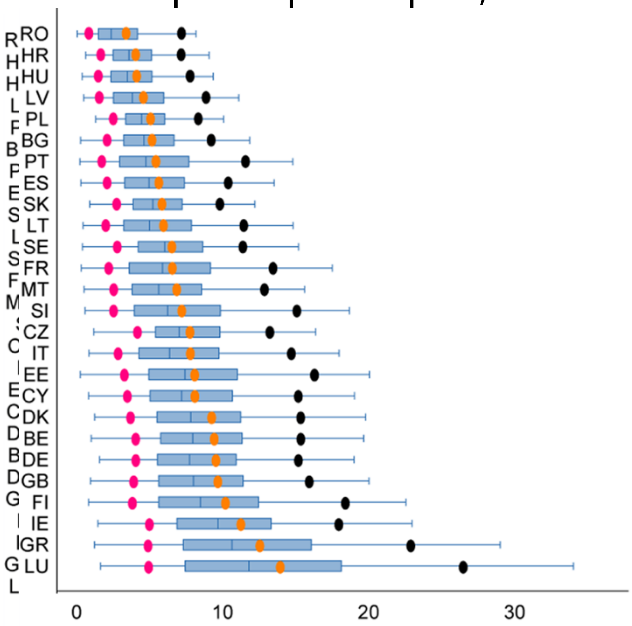


Figure 2: Distribution of carbon footprints per capita.

The orange circles represent the average carbon footprint per capita. The boxes describe 25th percentiles (left hinge), median and 75th percentiles (right hinge), and the whiskers describe the minimum and the maximum in the absence of outside values. The pink and grey circles describe each country's 10th and 90th percentiles, respectively.

Source: Ivanova D. and R. Wood (2020), "The Unequal Distribution of Household Carbon Footprints in Europe and its Link to Sustainability", *Global Sustainability*, 3, e18, pp. 1–12

LifestyleChallenges should primarily target lifestyle changes that promote large-scale shifts towards plant-based diets, reductions in motorised transport and energy-efficient housing while considering carbon inequality in the EU and across countries, regions and social groups

4.2 Transport

The highest mitigation potential of options usually reviewed in studies is found in the domain of transport, which is associated with a substantial carbon footprint in most countries in the world. Lifestyle change options in the mobility sector generally "show high mitigation potential and high-income elasticity of demand (i.e. there is a strong link between income and mobility emissions" (Capstick et al. 2020).

This suggests that measures to reduce emission across this sector can be relatively equitable and target "luxury" consumption by higher-income households. A reduction in car and air travel and a shift toward more minor carbon-intensive fuel sources, means and modes of transportation are standard lifestyle change options incorporated in modelling studies and are clearly identified as priorities.

Annual mitigation potential of consumption options for transport

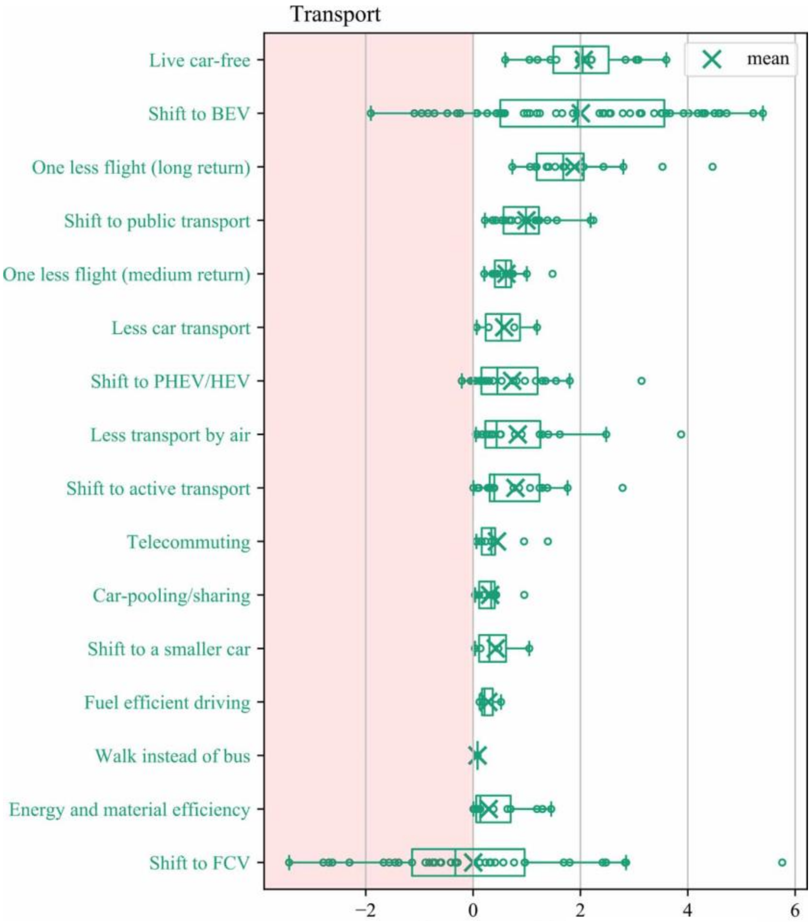


Figure 3: Annual mitigation potential of consumption options for transport.

Negative values (in the red area) represent the potential for backfire. The dots represent single reviewed studies, and the x–s—the average mitigation potential within the same consumption option. The 25th percentile, median and 75th percentile are noted with lines, with the options ordered by medians.

Source: Ivanova, Diana et al. (2020), "Quantifying the Potential for Climate Change Mitigation of Consumption Options", *Environmental Research Letters*, 15 (093001)

4.2.1 Individual car

Driving a petrol or diesel car inevitably has a significant carbon footprint as of all the CO_2 emitted over the lifetime of an internal combustion engine car, more than 80% comes from the use phase.

For those using a petrol or diesel car, driving more efficiently can start helping with their carbon footprint. Up to 15% of automobile fuel can be saved by diminishing the speed or simply observing the speed limit (Center for Sustainable Systems, 2021). The recent decisions by municipalities such as Brussels and Paris to lower speed limits in towns to 30 km/h is part of this logic. The model that people decide to buy is also essential since the carbon footprint of a large SUV can be double or triple that of a small compact car.

The mitigation potential of shifting from a petrol or diesel car to a BEV varies widely across regions due to the difference in the electricity mix. In their study, Ivanova *et al.* (2020) estimate the mitigation potential of driving a BEV between 5.4 and -2 tCO_2e/cap, with an average of 2.0 tCO_2e/cap. In comparison, the carbon reduction potential for (plug-in) hybrid electric vehicles (PHEV/HEV) varies between 3.1 and -0.2 tCO2e/cap (Ivanova et al, 2020).

The carbon intensity of the electricity mix is the primary determinant of the reduction potential of BEVs; the electricity mix alone explains almost 70% of the variability between regions.

It can be noted that, modelling studies are often based on the average grid carbon intensity. However, the marginal emissions factor may be substantially higher if gas or coal-fired plants meet additional demand from BEV. The International Energy Agency estimates that "a high-carbon electricity mix (800 gCO2-eq/kWh) eliminates any potential GHG savings with the shift to BEV" (IEA, 2021).

Using biofuels rather than oil-based fuels could also be an option. However, "*there are significant uncertainties around the mitigation potentials of biofuels due to inconsistencies in scope definition, assumptions (e.g. impacts of infrastructure and coproduction), and technological choices. For example, suppose system boundaries are expanded to include indirect land-use change (LUC), physical land constraints from food and feed, biodiversity conservation, as well as the temporal effects on natural carbon stocks. In that case, biofuels are revealed as a less attractive if not detrimental option for climate change mitigation*." (Ivanova et al, 2020).

4.2.2 Public transport and active travel

Reducing car travel is associated with substantial mitigation potential. The Living car-free scenario exposed by Ivanova *et al.* (2020) has the highest median mitigation potential across all reviewed options. However, the assumptions around vehicle and fuel characteristics and travel distance highly influence the estimated mitigation potential.

Partial car reductions (generally replacing short and urban car trips with public transport or active transport or reducing leisure trips, which represent a relatively small portion of all travel and its embodied emissions) have a much more limited average mitigation potential.

Emissions from mobility can be reduced through greater use of public transport and more active travel such as cycling and walking. However, the environmental benefits of switching from a private car to public transport will depend on the energy used by public transport. For example, metros and tramways use electricity, and their carbon footprints depend on the local grid's electricity mix. On the other hand, buses traditionally run on diesel, although some cities have started expanding their low carbon buses fleet (such as electric or hybrid buses, hydrogen FCEV buses, biofuels).

Shifting to public transport is nevertheless efficient in reducing carbon. Public transport alternatives will nearly always "have much lower carbon intensities per travel km than private petrol or diesel cars. Public transport is characterised by average carbon intensities at 0.09 $kgCO_2e$ per km, while individualised motorised transport at 0.23 $kgCO_2e$ per km" (Ivanova et al., 2018).

Reducing motorised transport even more by "replacing all local land transport with biking and walking can potentially mitigate the carbon footprint of households by nearly 25%" (Vita et al., 2019). However, the shift from public transport to active transport offers marginal mitigation potential per capita.

4.2.3 Air travel

There is also substantial mitigation potential to reduce emissions from mobility by avoiding or curtailing air travel for those who fly. However, the overall mitigation potentials depend on income, as high-income households fly much more.

Commercial aircraft GHG emissions vary according to aircraft type, trip length, occupancy rates, and passenger and cargo weight. The average carbon intensity of air passenger transport is estimated at 90 grammes of CO_2 per revenue passenger kilometre (gCO_2/RPK). Small planes like regional and jet flights (less than 100 seats) are more carbon-intensive, with an estimated 160 gCO_2/RPK. Short flights (less than 1000 km) are even more carbon-intensive, up to 300 gCO_2/RPK, because of the extra fuel used to take off (Graver et al., 2020).

Premium passengers are estimated to emit four times more GHG than economy passengers on the same flight. In other words, small planes, short flights, and premium class travel should be avoided and replaced by (potential) alternatives such as the train. However, considering the total footprint of a trip (and note the carbon intensity calculated by the quantity of CO_2 emitted per kilometre), it is the long-distance flights that should be targeted.

While rail can be a potential low carbon alternative to short-distance flights (within the EU, for instance), there are no low-carbon alternative means of transportation for long-distance travel (transcontinental, for instance). Therefore, reducing GHG emissions from air travel might imply giving up long-distance travel.

Reducing long-haul flights has a solid potential to reduce emissions equitably: "*air travel accounts for around 40 per cent of the carbon footprint of top 1% emitters in the European Union, but less than 1 per cent of the emissions of the poorest 50 per cent of households. Although this mitigation option only targets the wealthiest people who fly, its emissions reduction potential is estimated at around 1.9 tCO_2e per avoided long-haul return flight, which is substantial*" (Ivanova et al., 2020).

All lifestyle change options in the domain of transport offer essential co-benefits. For example, adopting public transport or active travel will reduce GHG emissions, lower local air pollution, and reduce urban congestion. Individuals with frequent walking or cycling habits also demonstrate improved mental and physical health compared to their inactive counterparts.

The option that offers fewer co-benefits is switching from an internal combustion car to an EV. Doing so does help to reduce carbon footprint (providing that the grid delivers renewable electricity) and diminish local toxic emissions, but does not reduce urban congestion, increase the practice of physical activities, or offer more reading time in public transport.

4.3 Diet

4.3.1 A Significant Carbon Footprint

Food is a significant source of household emissions, representing about 30% of EU household carbon footprint. However, it varies across regions and categories of households. These variations are primarily associated with differences in the consumption of animal products. The relative importance of food in the household's carbon footprint is typically higher in lower-income households.

The production process accounts for two-thirds of GHG emissions associated with food, while transportation accounts for 5% (Center for sustainable systems, 2021). The relative share of transportation might be substantially higher for fresh products that need to be transported by plane long distances. Therefore, eating local products instead of products imported from far away could significantly mitigate this kind of product.

Red meat and dairy dominate food footprints, as "animal-based foods are much more resource-intensive and environmentally impactful to produce than plant-based foods" (Ranganathan, J. et al. 2016).) In addition, meat products have a far larger carbon footprint per calorie or protein delivered than grain or vegetable products. This is due to the inefficient "conversion of plant to animal energy and the methane (CH_4) released from manure management and enteric fermentation in ruminants such as cattle, sheep, and goats" (Center for Sustainable Systems, 2021).

Ruminants alone are responsible for nearly half of agricultural production-related GHG emissions without considering land-use impacts. These "emissions associated with land-use change (LUC) are significant in meat-intensive diets due to increased pasture land and arable land for growing feed" (Ivanova et al., 2020).

For these reasons, studies unanimously suggest that adopting a vegetarian or a vegan diet is the best way to reduce individuals' carbon footprint immediately and longer term, as curbing agricultural expansion will also avoid future GHG emissions from land-use change. In addition, although less important, simply switching to less carbon-intensive meats can also have an appreciable impact. For instance, beef's GHG emissions per kilogram are estimated to be more than seven times greater than chicken (Center for sustainable systems, 2021).

It has been estimated "that reducing the consumption of animal-based foods among the world's wealthier populations could enable the world to adequately feed 10 billion people by 2050 without further agricultural expansion" (Rangathan et al, 2016).

4.3.2 Models and their limits

It is not just the type of products consumed that drives agriculture's environmental and resource use impacts, but also the way that food is produced. Most models are trying to picture the food carbon footprint and establish the best lifestyle change scenarios to mitigate it and show significant uncertainties, primarily associated with environmental and nutritional data.

Many models try to quantify the GHG emissions of different foods and food production types and then analyse the effects of diet shifts on the agricultural carbon footprint. The best models incorporate estimates of the GHG emissions generated throughout the production chain, including from the energy used to run farm machinery, produce and apply pesticides, and LUC.

However, most impact assessment studies generally do not consider emissions associated with LUC, although they are a vital element to provide a complete picture of the consequences of people's choice of diet. "*For all food types, the annualised land-use change emissions are far higher than emissions associated with agricultural production*" (Ranghathan et al, 2016).

For instance, "*when considering production emissions only, consumption of a million calories of beef would generate 19 tons of CO_2e, while the same quantity of pulses would generate 0.4 tons of CO_2e. Nevertheless, when factoring in LUC, emissions would climb from 200 tons of CO_2e for beef to 7 tons of CO_2e for pulses*" (Rangathan et al., 2016).

Annual mitigation potential of consumption options for food

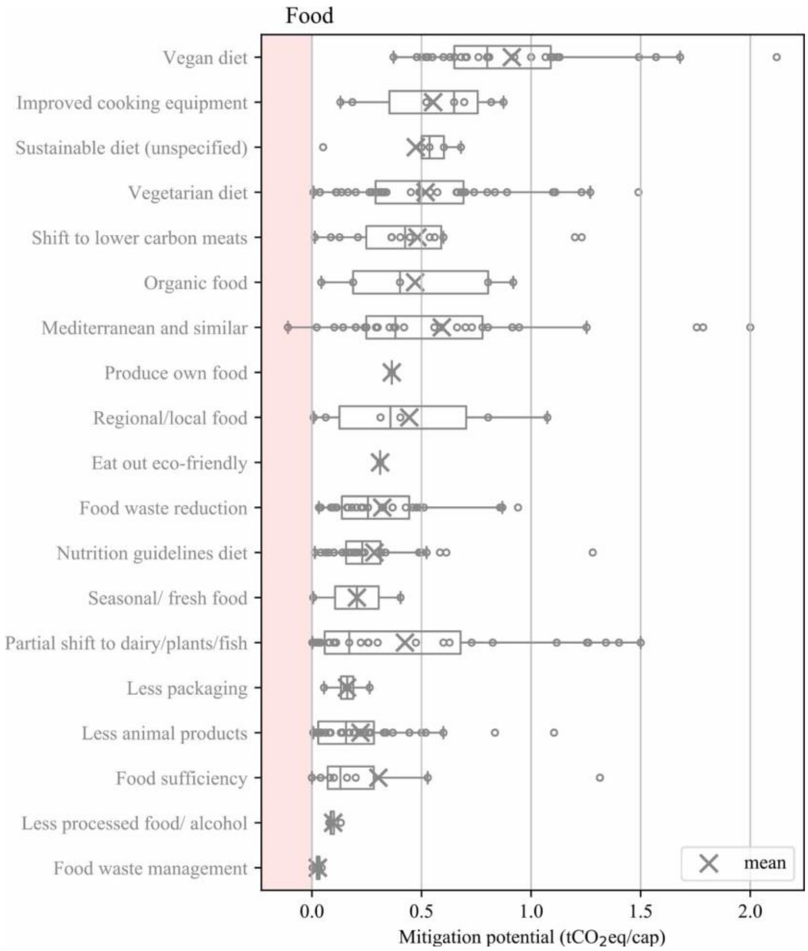


Figure 4: Annual mitigation potential of consumption options for food (in tCO_2e/cap).

Negative values (in the red area) represent the potential for backfire. The dots represent single reviewed studies, and the x–s—the average mitigation potential within the same consumption option. The 25th percentile, median and 75th percentile are noted with lines, with the options ordered by medians.

Source: Ivanova, Diana et al. (2020), "Quantifying the Potential for Climate Change Mitigation of Consumption Options", *Environmental Research Letters*, 15 (093001)

4.3.3 Main scenarios

The usual lifestyle change scenarios focus on a shift towards vegetarian or vegan diets for food. These two options are the most efficient, offering substantial potential for carbon mitigation. Further options for emission reductions exist, including reducing the overconsumption of calories and/or proteins, reducing meat (or just red meat), consumption of locally grown, seasonal and organic food, and reducing food waste. Improving cooking equipment can substantially impact developing countries where access to modern energy for cooking is often lacking.

Food sufficiency

In most developed countries, calories and protein consumption exceeds (sometimes vastly) estimated dietary requirements. According to the FAO, "*the global average daily energy requirement for an adult is 2,353 calories per day, although individual energy requirements depend on age, sex, height, weight, level of physical activity, and pregnancy or lactation. The average daily protein requirement for adults is around 50 grams per day, although individual requirements vary, as they do for energy*" (FAO, 2015).

In reality, global average protein consumption amounts to "*approximately 68 grams per person per day, i.e. more than one-third higher than the average daily adult requirement. In the wealthiest countries, protein consumption is much higher*" (Tartarini, 2020). For example, in Europe, the average daily protein intake is estimated above 85 grams, and over 90 grams in North America. In addition, the share of animal-based protein is gaining importance in people's diets relative to that of plant-based protein.

Overconsumption of protein (especially animal-based proteins such as meats, dairy, fish, and eggs) contributes to damaging the climate as animal-based foods are typically more resource-intensive and environmentally impactful to produce than plant-based foods. The "*production of animal-based foods accounted for around two-thirds of agriculture's production-related GHG emissions and more than three-quarters of global agricultural land use, contributing to less than 40% of total protein consumed by people*".

Therefore, reducing the overconsumption of proteins could significantly reduce the environmental footprint associated with food by reducing agricultural resource use and land use.

As with proteins, overconsumption of calories drives unnecessary agriculture inputs and unnecessary environmental impacts. "*It also contributes to people becoming overweight and obese, harming human health and contributing to rising healthcare costs and lost productivity*" (Rangathan et al, 2016).

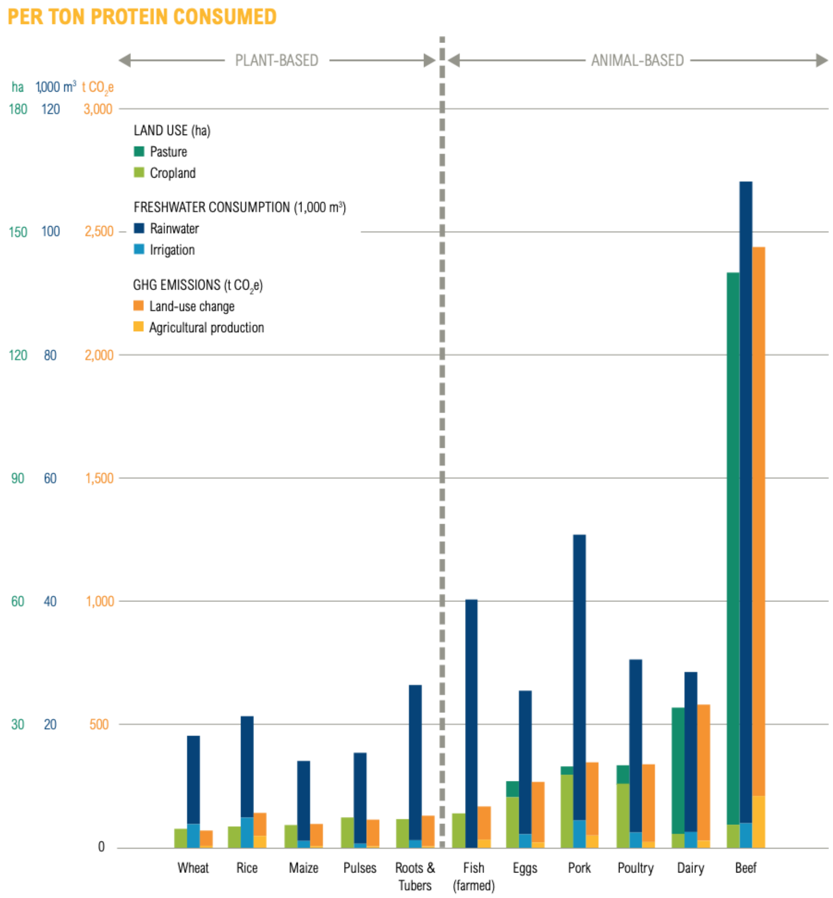
Scenarios of Food Sufficiency (consisting of limiting the calorific intake to a sufficient amount for European standards of 2586 kcal/day) found that such lifestyle change may reduce a household's total carbon footprint by 4% on average, and much higher when targeting above average meat-eaters (Vita et al., 2019).

No beef or red meat diets

Beef production is a significant driver of agricultural resource use globally. Ruminants are responsible for "*nearly half of GHG emissions from agricultural production. Given the environmental implications of the rising demand for beef, reducing its consumption is a priority*" (Rangathan et al., 2016). In a household used to eating red meat regularly, reducing beef consumption alone would significantly impact their GHG emissions.

From a "feed input to food output" perspective, beef is indeed one of the least efficient foods to produce. When considering all feeds, including crops and forages, it appears that "*only 1% of gross cattle feed calories and 4 per cent of ingested protein are converted to human-edible calories and protein, respectively. In comparison, milk, pork, poultry, farmed finfish and shrimp, and eggs convert animal feed to edible food at 6 to 13 times the efficiency of beef. Poultry, for instance, converts 11% of feed calories and 20% of feed protein into human-edible calories and protein*" (Rangathan et al., 2016).

The environmental footprint of various food products



Sources: GlobAgri model (land use and greenhouse gas emissions), authors' calculations from Mekonnen and Hoekstra (2011, 2012) (freshwater consumption), and Waite et al. (2014) (farmed fish freshwater consumption).

Notes: Data presented are global means. Entries are ordered left to right by amount of total land use. Indicators for animal-based foods include resource use to produce feed, including pasture. Tons of harvested products were converted to quantities of calories and protein using the global average edible calorie and protein contents of food types as reported in FAO (2015). "Fish" includes all aquatic animal products. Freshwater use for farmed fish products is shown as rainwater and irrigation combined. Land use and greenhouse gas emissions estimates are based on a marginal analysis (i.e., additional agricultural land use and emissions per additional million calories or ton of protein consumed). Based on the approach taken by the European Union for estimating emissions from land-use change for biofuels, land-use change impacts are amortized over a period of 20 years and then shown as annual impacts. Land use and greenhouse gas emissions estimates for beef production are based on dedicated beef production, not beef that is a coproduct of dairy. Dairy figures are lower in GlobAgri than some other models because GlobAgri assumes that beef produced by dairy systems displaces beef produced by dedicated beef-production systems.

According to Ranganathan (2016), because of this low conversion efficiency, beef uses more land and water and generates more GHG emissions per unit of protein than any other food product commonly included in people's diet. For example, ruminant production generates "*more than 20 times more GHG emissions than pulses per unit of protein consumed and require up to 28 times more land per calorie consumed than the average of other livestock categories. In addition, beef production consumes two to four times more freshwater than other livestock categories and up to 7.5 times more freshwater than plant-based foods per unit of protein delivered*" (Rangathan et al., 2016).

"*While sheep and goat are also highly inefficient—with similar conversion efficiencies to beef—they are consumed in smaller quantities globally. Beef accounted for 12% of global animal-based protein* *consumption in 2009 against only 2% for sheep and goat combined*" (Ranghathan et al, 2016).

Beef consumption has the most significant environmental impact of all commonly consumed foods because of its low efficiency in converting feed inputs to human edible calories and protein.

Therefore, a diet that reduces beef consumption has significant benefits and is theoretically relatively easy to implement since it only affects one type of food. Interestingly, some high-consuming countries (notably Europe) have already reduced beef consumption per capita from historical highs, suggesting that further change is possible.

Even replacing beef with pork or poultry should be impactful as they both show a significantly lower carbon footprint than beef. Poultry and pork have similar GHG emissions and land use per unit of protein consumed. However, "*poultry's land use and emissions are higher than pork's per calorie consumed mainly because of the high energy content of pork fat*" Ranghathan et al, 2016).

The Mediterranean, vegetarian and vegan diets

All low-meat diets provide environmental footprint reductions to some extent. For example, a Mediterranean diet (restraining red meat intake and increasing legumes, oils, vegetables, cereals, fish and dairy) is associated with moderate potential reductions (0.3 tCO_2e/cap on average). In comparison, a complete Vegetarian diet would reduce carbon footprint twice as much (0.5 tCO_2e/cap on average) (Ivanova et al., 2020).

Switching entirely to plant-based diets and adopting a Vegan diet is the lifestyle change that offers the highest carbon savings from all usually tested dietary changes. Dairy products, egg GHG emissions, and land use are essential, even higher than poultry per unit of protein consumed.

Vegan diets could reduce household carbon footprint by nearly 15% and spare 4% of the land as a co-benefit (Vita et al., 2019), which represents an average mitigation potential of 0.9 tCO_2e/cap, nearly twice as much as adopting a vegetarian diet.

Organic, seasonal and local food

Other options for carbon footprint reductions in the food domain is threefold: (1) production methods, (2) transportation and (3) seasonality.

Organic food has lower emissions than conventionally produced food, with an average annual mitigation potential of 0.4 tCO_2e/cap (nearly equivalent to adopting a vegetarian diet)(Ivanova et al, 2020). This mitigation potential is primarily attributable to the increased soil carbon storage and reductions of fertilisers and other agrochemicals. Nevertheless, increases in GHG emissions from organic food for the same diet are not uncommon due to lower crop and livestock yields of organic agriculture.

Opting for local or seasonal food diets involves additional carbon footprint reductions (0.4 and 0.2 tCO_2e/cap, respectively). In addition, producing and consuming "*food in its natural season does not require high-energy input from artificial heating or lighting, thus reducing the embodied GHG emissions*" (Ivanova et al., 2020).

Eating local products may cut down emissions from transportation and reduce impact displacement overall. For example, eating an apple in spring in Germany or France means that the apple has been either stored for months (using twice the energy as a fresh local apple produced in autumn) or transported from New Zealand or South Africa, requiring two to three times the energy due to the distance involved.

It is not rare that regional productions require heating systems (for instance, for fresh vegetables at the beginning of the growing season). In these cases, local production "may be associated with higher emissions than relatively long-distance transport emissions from production sites without heating (e.g. Morocco)" (IvanovaIvanavo et al, 2020).

In Europe, where a large share of imported food is consumed, the Seasonal food scenarios (based on a reduction of energy inputs to agriculture by a third) usually have no significant mitigation potential. "*However, in a scenario where a larger share of food is produced in Europe (Local food),* *the effects of seasonal food are more significant*" (Vita et al., 2019).

Policies favouring synergies between Organic, Seasonal and Local agriculture can lead to dynamic effects with significant carbon footprint mitigation potential.

Less waste

Substantial mitigation potential is also associated with reducing food waste, knowing that studies generally consider that 80% of all food waste is avoidable or potentially avoidable. Dramatically reducing food waste and the surplus could reduce the household's carbon footprint by 2 to 5% and mitigate an average of 0.3 tCO_2e/cap (Ivanova et al., 2020).

Most of the lifestyle change options suggested in food are strongly associated with co-benefits. As current European diets are characterised by an intake of calories and animal products above dietary recommendations, switching diet from high saturated-fat, high-calorie meats to one based on fibre-rich foods, fruits and vegetables offer many positive health and economic outcomes. Obesity is a risk factor for several diseases, including hypertension, diabetes, cardiovascular diseases, and certain types of cancer, increasing the risk of premature death. Moreover, the health impacts of obesity drive up healthcare costs: obese people on average incur 25 percent higher healthcare costs than a person of average weight. Ultimately, obesity can negatively impact productivity (Rangathan et al, 2016).

Adopting a plant-based diet and reducing the intake of calories and proteins have many benefits beyond mitigating the carbon footprint. Last but not least, "*modern livestock systems that concentrate animals for all or part of their lives can also give rise to animal welfare concerns, while the use of antibiotics to prevent infections in concentrated livestock production systems also raises indirect human health concerns*" (Ranghathan et al, 2016).

A common obstacle to adopting a meat-free diet comes from the belief that animal-based foods are better sources of protein than plant-based foods. For that reason, meat is often considered more desirable than plant-based food.

This belief is a myth, which "*stems from the fact that animal-based foods provide a complete source of the essential amino acids that humans need, while plant-based foods—except for a few such as soy and quinoa—lack some amino acids. However, plant-based foods can be combined to provide the complete set of essential amino acids, like rice and beans or peanut butter and bread. Furthermore, while meat also contains high levels of essential micronutrients, including iron, A and B vitamins, and zinc, a diverse plant-based diet can also provide an adequate supply of micronutrients. The only exception is Vitamin B12, which occurs naturally in animal-based foods but is available in supplements*" (Ranghathan et al, 2016).

4.4 Housing

About 20% of the carbon footprint of EU households is associated with housing. The shelter footprint per capita ranges typically between 1 tCO_2e/cap (in the Mediterranean countries) and 2 tCO_2e/cap (in Finland)(Ivanova et al., 2017).

The energy used for heating at home accounts for half of the average European household's carbon footprint associated with housing. This explains a large part of the carbon footprint variation among locations. The other half of the housing carbon footprint is largely due to the electricity used for lighting, hot water, all the household appliances, and in some cases, air-conditioning, and BEV charging.

Annual mitigation potential of consumption options for housing

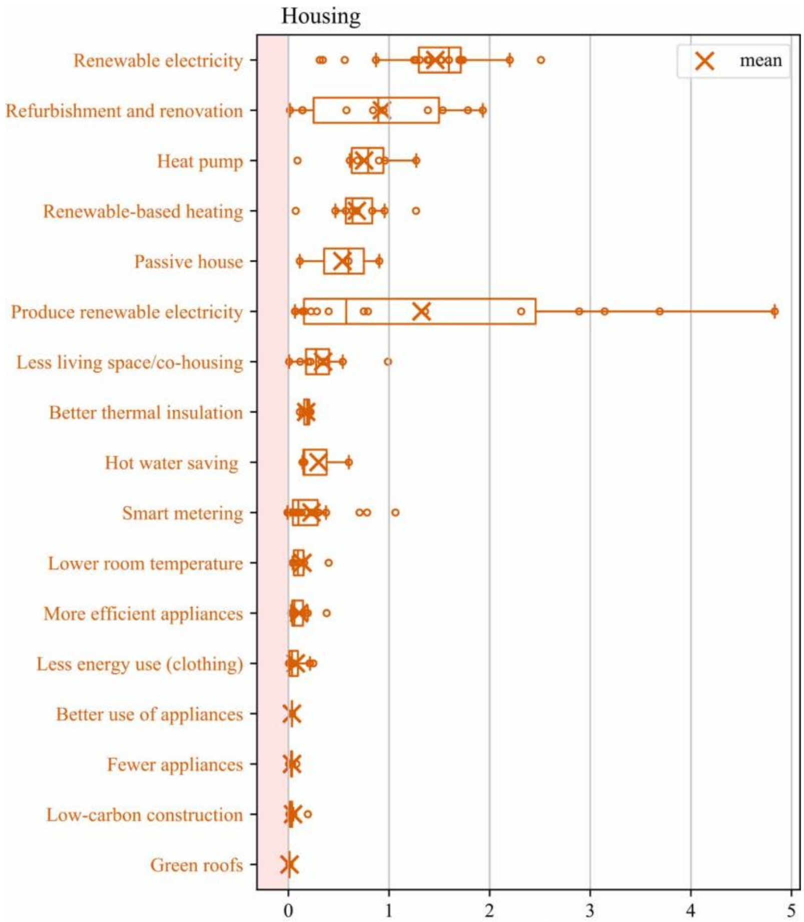


Figure 5: Annual mitigation potential of consumption options for housing. (in tCO_2e /cap)

Negative values (in the red area) represent the potential for backfire. The dots represent single reviewed studies, and the x–s—the average mitigation potential within the same consumption option. The 25th percentile, median and 75th percentile are noted with lines, with the options ordered by medians.

Source: Ivanova, Diana et al. (2020), "Quantifying the Potential for Climate Change Mitigation of Consumption Options", *Environmental Research Letters*, 15 (093001)

In most studies, lifestyle change options related to residential consumption show relatively high mitigation potential (Girod et al., 2014; Ivanova et al., 2016; Lacroix, 2018; Moran et al., 2018; Schanes et al., 2016). However, many of these options present a low-income elasticity of demand: they are related to primary or essential consumption. They, therefore, are dependent on the context (climate type, for instance) rather than on the socio-economic category of the household.

The methodological differences are extreme between studies in the housing domain. Given all the necessary hypotheses and the wide range of contextual factors, the mitigation potential of specific lifestyle changes is challenging to calculate. Factors such as climate differences, dwelling type, rate of adoption and usage of air-conditioning systems, and share of renewables in the local grid greatly influence the carbon savings potential of lifestyle options being tested.

From all the scenarios, the mitigation options with the highest potential on average include purchasing renewable electricity, producing renewable electricity, and refurbishment and renovation (with an average saving of 1.5 tCO_2e/cap, 1.3 tCO_2e/cap and 09 tCO_2e/cap, respectively)(Ivanova et al., 2020).

This is not surprising given that half of a household's carbon footprint comes from electricity and the second half from heating. Additionally, opting for renewable electricity rather than fossil-based electricity leads to a reduction of global environmental pollution, which is, on a societal scale, a benefit for public health.

Shifting to renewable electricity seems effortless, as nearly all energy suppliers in Europe offer "green" electricity tariffs for a moderate additional cost. Nevertheless, unfortunately, in reality, the situation is more controversial.

How Green is "Green Electricity"?

Consumers connected to the electricity grid do not choose who produced their electricity. Instead, they consume what the grid delivers, i.e. electricity produced according to the national or local electricity mix. The only difference when buying "green electricity" is that the supplier provides certificates (called Guarantees of Origin, GOs), stating that renewable electricity has been injected into the grid... somewhere in Europe. GOs are typically issued by wind, solar and hydropower plant operators. They are bought by energy suppliers who want to sell "green electricity" to their clients without producing it.

The problem is that the consumers who buy the electricity with GOs believe that their electricity is green, although it is not the case: the electricity is produced locally, based on the local electricity mix. For instance, in the Netherlands, where a large majority of households opted for "green electricity", only a quarter of the electricity produced is renewable. So instead, Dutch electricity suppliers import GOs from Norwegian or Austrian hydropower plants to disguise fossil-based electricity as green.

Conversely, actual green power is disguised as a fossil in the country where the GOs have been issued. As a result, consumers that use renewable electricity (in Norway, for instance) appear, on paper, to be accountable for the emissions from the fossil-based electricity produced elsewhere without knowing it. In a country like Norway, where hydropower accounts for 95% of the electricity mix, consumers do not need a "green electricity" tariff (Hamburger, 2019).

Some electricity suppliers are genuinely "green": those who produce the green electricity they sell. Therefore, only that kind of green electricity provider should be encouraged in LifestyleChallenges.

As heating contributes to an essential part of a household's carbon footprint, infrastructure-related options associated with space heating offer high mitigation potential, especially renovating the dwelling, installing a heat pump, and living in a passive house. Other effective alternatives include "*opting for a heat pump and renewable-based heating. This offers an average mitigation potential of about 0.8 tCO_2e/cap, while the shift to a passive house is associated with an average reduction potential of 0.5 tCO_2e/cap, excluding GHG emissions associated with infrastructure changes. The carbon intensity of materials and geographical differences in energy and heating requirements and temperature tolerance are critical factors for the absolute mitigation potential associated with the different options regarding housing*" (Ivanova et al., 2020).

These options, which are not strictly related to lifestyle, involve significant investment capacity. Therefore, they are concerned about life decisions rather than everyday behaviours. However, given that 70% of European households own their dwelling (Eurostat, 2018). Furthermore, it can thus influence the energy efficiency and materials in their houses. Therefore, some Lifestyle Challenges should be designed to target these specific moments of a household's life when critical decisions impacting the carbon footprint are made.

Other behavioural changes, such as (1) saving hot water, (2) lowering room temperature by 1◦ C, (3) reducing the usage of washing machines and tumble dryers (two of the most energy-consuming appliances of the households), (4) unplugging electronic devices when not in use, (5) choosing more energy-efficient lighting and appliances can help to reduce household GHG emissions but only marginally.

Installing a Smart meter can be interesting to improve "*household awareness of their energy consumption and support energy reduction activities (e.g. it may encourage retrofitting of houses or change of appliances and equipment)*" (Ivanova et al, 2020).

4.5 Other Consumption

Some studies also tested specific lifestyle change options related to household consumption, including fashion. Amongst these options, those with the most substantial carbon footprint mitigation potential include not having a pet and opting for the service/sharing economy in which people share and consume services instead of goods (such as using a bike-sharing system instead of owning a bike) (Girod et al., 2014; Moran et al., 2018; Schanes et al., 2016; Wood et al., 2017).

Annual mitigation potential of other consumption options

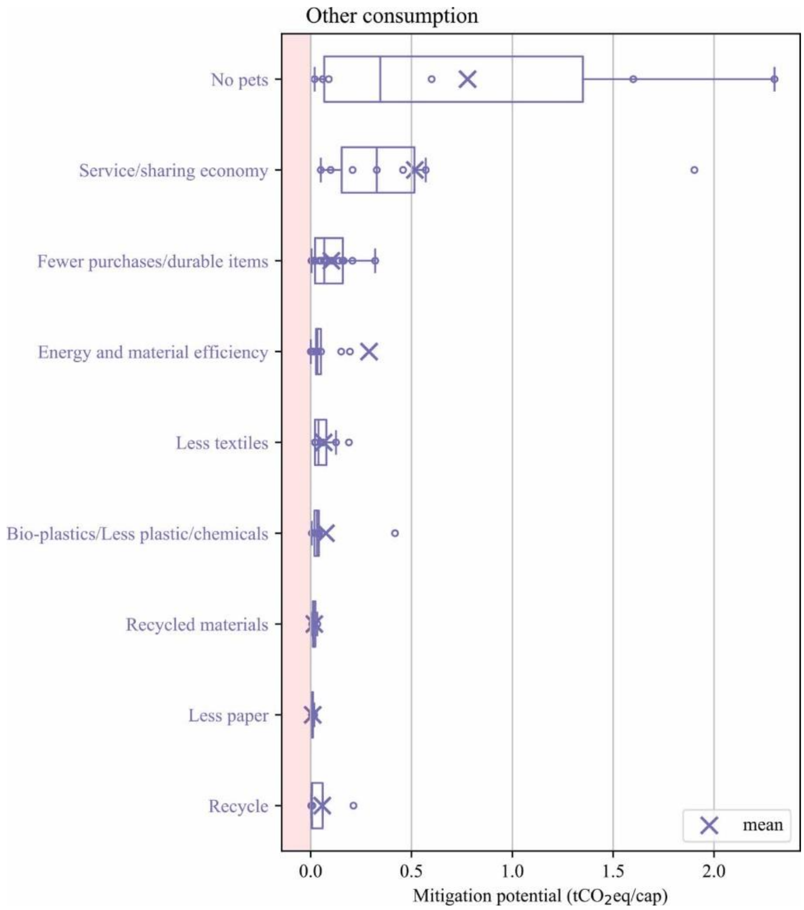


Figure 6: Annual mitigation potential of other consumption options (in tCO_2e/cap).

Negative values (in the red area) represent the potential for backfire. The dots represent single reviewed studies, and the x-s—the average mitigation potential within the same consumption option. The 25th percentile, median and 75th percentile are noted with lines, with the options ordered by medians.

Source: Ivanova, Diana et al. (2020), "Quantifying the Potential for Climate Change Mitigation of Consumption Options", *Environmental Research Letters*, 15 (093001)

Models testing this sharing economy option usually assume that increased sharing, reparability and re-use are possible, but it is not always the case in reality.

Making clothes last longer (e.g., repairing and increasing secondhand re-use) can also lead to a noticeable carbon footprint reduction. Clothing contributes to about 4% of total EU household emissions (and up to 5%–7% in Italy)(Vita, 2019).

Unfortunately, we have not found any studies in academic literature assessing carbon footprint mitigation options related to households' online and digital consumption (such as video and audio streaming, social media, internet, emails, cloud storage). As the world becomes increasingly digitalised, demand for data centre services rises rapidly, requiring a vast amount of electricity and adding pressure to electricity grids, especially in smaller countries. Data centres worldwide consume about 1% of global electricity use (IEA, 2019).

Amongst the co-benefits of "*relying less on market services and more on a shared economy are social empowerment and a sense of community*" (Vita et al. 2019).

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5. Target Lifestyles

5.1 Carbon footprint and inequalities

The distribution of household carbon footprints is vastly unequal within and across countries, and these differences in consumption and carbon trends between the highest and the lowest EU emitters is an essential factor to consider (Oswald *et al.*, 2020).

According to Ivanova and Wood (2020), the top 10%, middle 40% and bottom 50% of the European households in terms of carbon footprint per capita contribute 38%, 43% and 8% of the EU total carbon footprint, respectively. The top 10% of the EU population with the highest carbon footprint contribute twice as much carbon compared to the 50% of the EU population with the lowest carbon footprint (with an average carbon footprint of 23 tCO_2e/cap and 5 tCO_2e/cap, respectively. The average carbon footprint of the "EU middle 40% emitters amounts to 10 tCO_2e/cap. While only 5% of the EU households live within a carbon footprint target of 2.5 tCO2e/cap, the top 1% of EU households have a carbon footprint above 55 tCO_2e/cap" (Ivanova and Wood, 2020).

Average carbon footprint distribution by consumption category (EU)

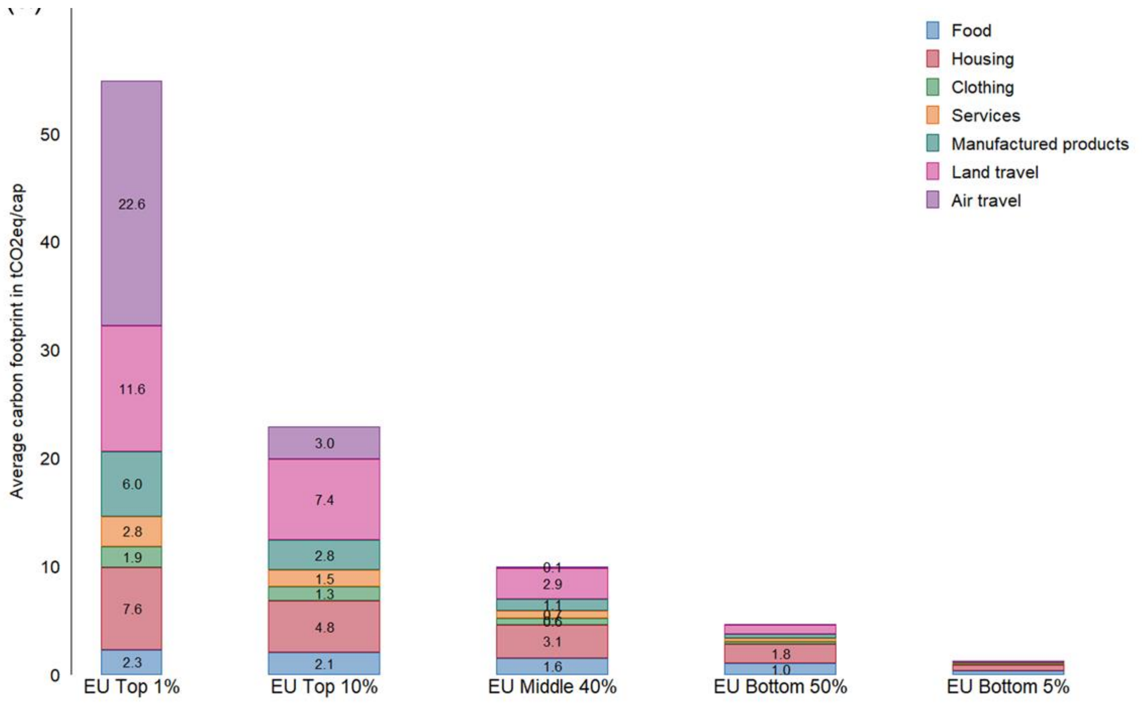

Figure 7: Average carbon footprint distribution by consumption category (EU).

Source: Ivanova D. and R. Wood (2020), "The Unequal Distribution of Household Carbon Footprints in Europe and its Link to Sustainability", Global Sustainability, 3, e18, pp. 1–12

The households with the most significant carbon footprint are by and large the households with the highest levels of income. The main reason is their land and air transport contributions to the footprint, which are disproportionally large. Even more so, land transport and air transport are highly carbon-intensive and highly elastic.[2]

Air and land transport contribute to more than 40% and 20% of the GHG emissions of the top 1% of EU households. Moreover, "*air transport has a rising elasticity coefficient across EU income quintiles, making it the most elastic, unequal and carbon-intensive lifestyle*" (Ivanova and Wood, 2020).

Average carbon footprint distribution by income quintile in the EU

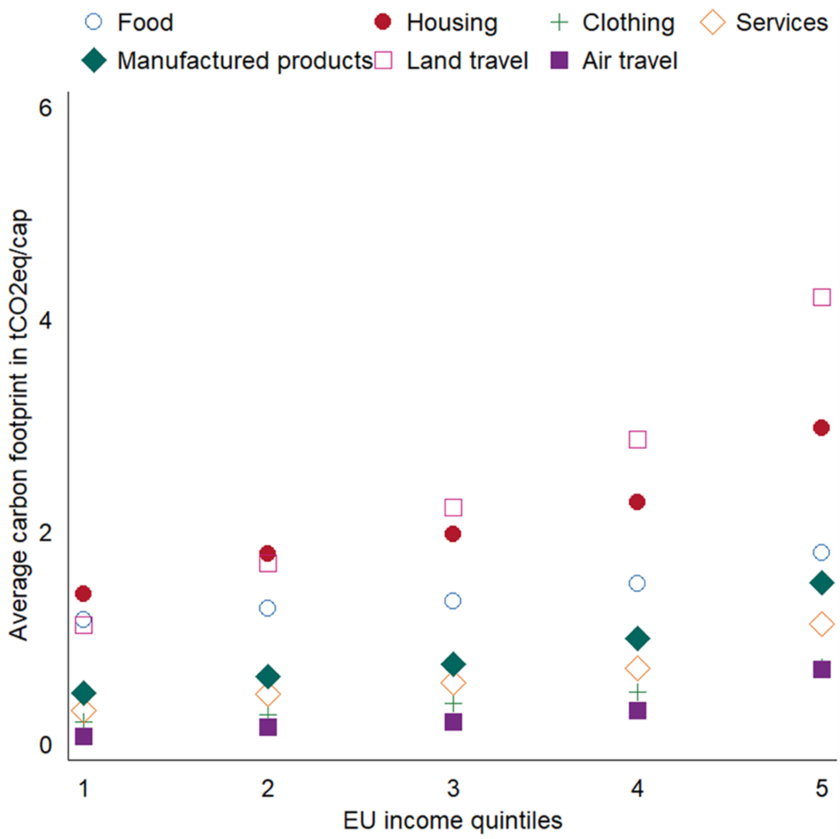

Figure 8: Average carbon footprint distribution by income quintile in the EU.

EQ1 contains households with annual expenditure levels below 6300 EUR in basic prices; 6300 EUR < EQ2 < 9300 EUR < EQ3 < 12,800 EUR < EQ4 < 18,700; EQ5 > 18,700 EUR.

Source: Ivanova D. and R. Wood (2020), "The Unequal Distribution of Household Carbon Footprints in Europe and its Link to Sustainability", Global Sustainability, 3, e18, pp. 1–12

[2] Income elasticities measure the responsiveness of expenditure on a specific product to a unit change in total income ("how much more am I going to spend on transport if I earn 1000 euros more?"). High elasticities of a product signal an increasing proportion of expenditure on the product with rising total expenditure. These are common for non-necessities (such as air travel), while low elasticities are typical for consuming necessities (food, heating).

Overall, those with the highest carbon footprint also have the highest income levels. Income and carbon footprint are strongly positively correlated, with a correlation coefficient of 0.65 for the whole of the EU (Ivanova and Wood, 2020). Income is the most critical determinant of transport emissions, mainly from air transport.

Similarly, there is a positive association between carbon footprint and education, with a correlation coefficient of 0.54 for the EU, however, with wide variation in the carbon footprint across countries at similar education levels (.Ivanova and Wood, 2020). The consumption categories of mobility, clothing and manufactured products are particularly income-elastic.

However, "the literature also underlines wide ranges in income, education, nutrition, employment and poverty for the same levels of carbon footprint, highlighting successful cases of low-carbon lifestyles and high levels of social well-being, as well as high-carbon, low-well-being cases" ()Ivanova and Wood, 2020).

5.1.1 The case of transport

The majority of GHG emissions of the top EU emitters are transport-related. In particular, "*air travel drives a carbon footprint of 22.6 tCO_2e/cap among the EU's top 1% households. Air travel represents about 40% of their total carbon footprint, making it the consumption category with the highest carbon contribution among the top emitters. The EU top 10% of households that fly, with an average air travel carbon footprint of the other 90% of the population below 0.1 tCO_2e/cap*" (Ivanova and Wood, 2020).

The carbon footprint "*associated with air travel increases with rising income. Air travel is by far the most elastic consumption in the EU, with an expenditure elasticity of 1.5; which means that, as total expenditure doubles (i.e. an increase by 100%), the expenditure on air travel increases by 150%*" (Ivanova and Wood, 2020).

On the contrary, the lowest-income quintile has an insignificant coefficient. This means that an increase in total spending does not lead to flying among the lowest spenders. In other words, air travel is a highly carbon-intensive luxury.

"Land travel is also associated with some of the highest consumption shares among the EU top 10% emitters" (Ivanova and Wood, 2020). Land travel (purchase of vehicles, transport fuels and services) drives about 20% and 30% of the average carbon footprint of the EU top 1% and top 10% of households, respectively. Land travel represents the consumption category with the highest contribution among the EU top 10% emitters (Ivanova and Wood, 2020).

Transport is "*one of the most unequally distributed and the strongest drivers of the carbon footprint of the rich. On the contrary, food and housing are necessities and are thus associated with much lower income elasticities than other consumption categories*" ()Ivanova and Wood, 2020). When products and services concern non-basic needs, household consumption can be mainly considered discretionary. Therefore, their reduction would not necessarily drastically impact the quality of life. Food is a basic need. However, "*given that the average per capita consumption of protein in Europe already greatly exceeds dietary requirements, it is possible to reduce animal-based protein consumption in over-consuming populations without the risk that diets will be deficient in protein*" (Rangathan et al., 2016).

As "*radical emission reductions in transport require decreases in the number of vehicles and travel distance and the shift to low-carbon transport modes, it must be taken into account that the land travel share of the lowest income quintile is not negligible (about 20%), only below basic needs such as food and housing*" (Ivanova and Wood, 2020).

This is important to consider, as it means that using a car is often a necessity (or seen as such) by the poorest people. They are the category of the population that devotes the largest share of their budget to transport-related expenses. For that reason, public policies that tend to increase the cost of using a car (through additional taxes, fees to access the city centre, etc.) impact the poorest more than the rest of the population, and therefore need to be accompanied with specific measures targeting the most vulnerable groups to avoid adverse effects (for instance by offering better public transport).

Switching from one transport mode (for instance, private car) to another (public transport or bicycle) must be seen from a dynamic perspective. For example, people might decide to make some of their journeys by bike instead of a car but not regularly (especially while going shopping, going to work or driving the kids to school), or not systematically (because of the changing weather conditions, for instance). LifestyleChallenges should therefore be designed to encourage people to try another behaviour and discover the potential alternative to their current lifestyle or push people to adopt a specific lifestyle behaviour more commonly or exclusively.

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5.2 Sufficiency Lifestyle vs Green Consumption

The available options to reduce lifestyle emissions can be divided into three categories: Avoid, Shift and Improve (Creurzig et al. 2018).

The first one, "Avoid", refers to reducing energy or carbon-intensive demand by sacrificing some aspects of consumption. These options involve giving up or avoiding certain behaviours or lifestyles—for example, reduced travel, fewer appliances, no meat diet.

The second category, "Shift", refers to shifts in behaviour to more minor carbon-intensive modes of consumption, i.e. a substitution *between* consumption categories such as opting for public transport, cycling or walking instead of private vehicles, or shifting to a vegetarian or vegetarian or Mediterranean diet.

The third category, "Improve", aims at reducing GHG emissions through improving efficiency or replacing technologies with less carbon-intensive ones without modifying the underlying consumption activity. It refers to substitution *within* a specific consumption category: keep using a private car, buy a more efficient one such as a BEV, keep an animal-based diet, and buy organically grown food.

Not all lifestyle changes involve the same active effort in changing the nature of consumption or the amount of consumption. For example, the Avoid category is about degrees of changing consumption volume. In contrast, the two others address qualitatively different ways of changing patterns of consumption and lifestyles: the Shift category moves toward a sufficiency lifestyle, while the Improve category opts for green consumption.

The two main scenarios for reaching carbon-neutral lifestyles propose options for reducing consumption "*(sufficiency scenario – implying net reductions in consumption) or consuming less polluting goods (green consumption – implying consuming more eco-efficient alternatives)*" (Vita *et al.*, 2019).

"*Sufficiency scenarios represent lifestyles that reduce material consumption and aspire to a higher quality of life, detached from materialistic constraints. Sufficiency assumes that well-being relies more on health, social relationships, and time affluence*" (Vita et al., 2019) once basic needs are satisfied. Sufficiency lifestyles are derived from voluntary simplicity and align with alternative economic models such as de-growth. Consequently, sufficiency lifestyles usually rely on options where the reduction in consumption allows to save money.

"*By contrast, green consumption stands for consumption lifestyles related to "green growth" economic models*" (Vita et al., 2019). The primary assumption is that economic growth is compatible with sustainability, thanks to technological improvement (e.g., renewable energies, electric cars), to the shift to service-based and circular economy, and to reduce waste by extending product lifetimes, and recycling. "*Under this paradigm, people aspire to sustainable use of resources without considering changing their current lifestyles and economic practices fundamentally*" (Vita et al., 2019).

Green consumption often implies options with a higher cost than current lifestyles. This is because they are replacing current technologies with lower-carbon ones (such as BEV, passive house, appliances of better quality that last longer). In some cases, costs might be a barrier to lifestyle changes even if they can often be considered an investment (that will generate savings).

Sufficiency options are generally more efficient to reach carbon neutrality and help save money. However, they are usually not as popular (amongst the population or the public authorities) as green consumption options because they conflict with prevailing economic growth paradigms. Lifestyle changes that either reduce consumption or reduce inputs to production imply a reduction in the GDP of the economy in the long run.

On the contrary, green consumption scenarios shift expenditure towards the goods that households perceived as more “environmentally-friendly”. However, although these lifestyles generate fewer GHG emissions, they also come at the potential risk of increasing land, water and resource requirements (Akenji, 2014).

"*Sufficiency options have overall higher mitigation potential in transport, services and clothing. In contrast, green consumption options show more impact in food and manufactured products, such as shifting towards plant-based diets, sharing and repairing appliances, retrofitting insulation for passive housing*" (Vita et al., 2019).

Sufficiency options also are usually associated with higher co-benefits. These co-benefits can be individual: saving money on the car, fuel, insurance, maintenance; spending less on food; having more reading time in public transport; improved health condition by adopting active travel and sufficiency diet. They can also be collective like less urban congestion by giving up cars, less air pollution, and support to local farming.

"*Green consumption and sufficiency can, in some cases, be complementary. Some scenarios are not mutually exclusive and may be implemented synergistically to yield more incredible benefits. However, except for switching to plant-based diets, the lifestyles with the most potential generally imply curbing consumption towards sufficiency levels*"(Vita et al., 2019).

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5.3 Targeting strategic moments

"*Household carbon footprints are not static, as consumption patterns can change significantly according to strategic decisions and major life events*" (Dubois et al., 2019). Although part of the footprint comes from GHG emissions related to daily consumption (such as eating, driving a car), other parts are related to vital strategic moments such as when a person decides where to live, how to build its house, whether to buy a car or not, whether to install an air conditioning system.

The consequences of these decisions on the household carbon footprint can be significant and permanent. Similarly, major life events such as having children, moving home, leaving children home, retiring or falling ill can also substantially affect emission trajectories.

Studies show that household footprints "*shift significantly over time following a household lifecycle as a function of major decisions (such as purchasing a car or home) or significant life events (such as having children or getting divorced*)" (Dubois, 2019). This underscores the necessity of targeting those specific events, especially as demographic attributes (household size, ownership status) are usually more significant than a geographic location in determining households' preferences for lifestyle changes towards a carbon-neutral lifestyle.

Household footprints and preferences for reducing them are relatively similar across countries but differ along with some demographic household characteristics. "*Differences between countries are less significant than differences linked to household profiles (e.g. heating type, travel habits). The home country or city of residence of the household does not significantly affect preferences; instead, differences between subjects are less country-specific but subject-specific and vary according to the level of income" (Dubois, 2019)*.

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6. Conclusion

Mobility and food accounted for about two-thirds of European households' carbon footprint. Therefore, targeting cars, air travel, and meat consumption is the priority, rather than focusing on household appliances and heating or electricity. The top lifestyle change options include "*substantial changes in car travel (living car-free, shifting to BEV, public transport and active travel), drastic reduction in air travel, use of renewable electricity and sustainable heating (renewable-based heating and heat pump), refurbishment and renovation, and a shift to plant-based diets*" (Ivanova et al., 2020).

However, changing people's consumption behaviour and lifestyles is difficult. "*Food choices, for instance, are influenced by a variety of interacting factors, including price and taste of the food; age, gender, health, income, geography, social identity, and culture of the consumer; and exposure to a variety of external factors, such as marketing, media, and ease of access to supermarkets and restaurants*" (Rangathan et al., 2016).

Moreover, household decisions are sequential and temporally dynamic, and a large part of their carbon footprint is related to lifestyle decisions that cannot be easily reversed, such as the type of dwellings, the distance between home and work, the efficiency of the household appliances.

The sustainability transformation certainly requires innovative technologies. It also requires innovative lifestyles and engaged, well-informed citizens. Raising awareness is an essential milestone on the road to sustainable lifestyles. However, studies show that there is often a mismatch between the roles and responsibilities conveyed by current climate policies and household perceptions of responsibility (Dubois, 2019).

Raising awareness on the climate changes issues, households' responsibilities, and the solutions offered to them to mitigate their carbon footprint is consubstantial to lifestyle changes. It starts with the need to convince part of the population (more than 10% of the citizens in several European countries including Austria, Sweden, France) that still believe that climate change is exclusively caused by nature (with no human responsibility), as pointed in the CAMPAIGNers Deliverable D 1.1.

During the last Eurobarometer survey (2021), only half of Europeans (49%) cited climate change as one of the world's most serious problems resulting in differences amongst countries. This rate rises to 74% in Sweden and 66% in Ireland but is lower than average in Lithuania, Greece and Italy (44%, 41% and 41%, respectively). On the other hand, France, Finland and Austria are close to the EU average (European Commission, 2021).

There is a generally low awareness amongst European citizens about their energy consumption and its carbon footprint, especially amongst the elders, the less educated and those who identify themselves as belonging to the working class (European Commission, 2021). As shown in the ECHOES survey, people are, for instance, largely ignorant on how hot water is produced at home, hence how to improve their environmental footprint regarding the use of hot water. The same occurs with the energy consumption for heating and the potential for carbon-saving (and money-saving) renovating dwellings. The level of awareness of the climate change threat is strongly correlated to their socio-professional category and their standard of living.

When asking people who, in their opinion, is responsible within the EU for tackling climate change, only 40% of European citizens mention "themselves personally". This rate varies widely amongst countries, with the Swedish (56%), the Irish (52%), the Austrians (48%) and the French (46%) being more aware of the role individuals can play in the fight against climate change, and the Italians (28%), Lithuanians (28%) and the Greek (33%) much more minor (EC, 2021). In these three last countries, individuals still need to be convinced that it is also their responsibility to get to grips with climate change.

Besides encouraging people to adopt a more carbon-neutral lifestyle, an essential role of the LifestyleChallenges will be to raise awareness amongst citizens on the challenges of global warming, their responsibilities, the consequences of their lifestyle behaviours the leverage they have reducing their carbon footprint. This is a necessary prerequisite for people to start moving towards a carbon-neutral lifestyle.

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