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1.5 Degree Lifestyles

Targets and options for reducing lifestyle carbon footprints

Technical Report

1.5-DEGREE LIFESTYLES:

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Institute for Global Environmental Strategies
Aalto University and D-mat ltd.

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Abbreviations

3EID	Embodied Energy and Emission Intensity Data for Japan Using Input–Output Tables
AR5	IPCC Fifth Assessment Report
BECCS	Bioenergy with carbon capture and storage
CCS	Carbon capture and storage
CO_2	Carbon dioxide
COICOP	Classification of individual consumption according to purpose
COP	Conference of the Parties
GHG	Greenhouse gas
GTAP	Global Trade Analysis Project
GLIO	Global link input-output
HFCs	Hydrofluorocarbons
IAMs	Integrated assessment models
INDC	Intended Nationally Determined Contributions
I/O	Input-output tables
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
LCA	Life cycle assessment
LCI	Life cycle inventory
LED	Light emitting diode
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LULUCF	Land use, land use change and forestry
MRIO	Multi-regional input-output tables
N_2O	Nitrous oxide
NGO	Non-governmental organisation
NSFIE	National Survey of Family Income and Expenditure
PFCs	Perfluorocarbons
RoW	Rest of the world
SF_6	Sulphur hexafluoride
UNEP	United Nations Environment Programme

Executive Summary

The urgent and unavoidable need to address lifestyles

This report demonstrates that changes in consumption patterns and dominant lifestyles are a critical and integral part of the solutions package to addressing climate change. However, so far, limited efforts have been made in the scientific literature and policy approaches to show the potential contribution that changes in lifestyles could make in keeping global warming within the limit of 1.5 °C as in the aspirational target of the Paris Agreement. The study conducted for this report is one attempt to fill that gap, and to begin to propose clear targets and quantifiable benefits to climate change solutions by making changes in our lifestyles. The results of the analysis are striking, showing in some cases the need for reductions of over 80% in greenhouse gas emissions (GHG) by 2050 from today's intensity of lifestyles. Reductions will be necessary not only for industrialised countries; several industrialising countries will also need to reduce average per capita emissions from current levels – a significant challenge where basic needs of large parts of their populations are often not met yet. However, as also identified in the report, there are clear opportunities for much needed changes, and these would require that actions start as soon as possible.

The Intergovernmental Panel on Climate Change (IPCC) Special Report on Global Warming of 1.5 °C has reinforced the need to urgently and drastically reduce GHG emissions in order to achieve the 1.5 °C target (IPCC 2018). Currently, the discussion on solutions to climate change is largely based on technology, despite the importance of behavioural change and systemic infrastructural changes (Creutzig et al. 2016; Akenji and Chen 2016). The IPCC Fifth Assessment Report (IPCC AR5) highlights the considerable influence of behaviour, lifestyles and culture, including consumption patterns and dietary changes, on emissions (IPCC 2014a). Shifting towards low-carbon lifestyles can have relatively quick impacts, especially in consumption domains that are not locked into existing infrastructure (e.g. Lettenmeier, Laakso, and Toivio 2017). Understanding the full extent of this would require consideration and analysis of potential impacts from household action on GHG emissions, which, to date, remains limited in the scientific literature on mitigation pathways.

This report has thus undertaken the challenge of examining GHG emissions and reduction potentials from consumption and lifestyles perspectives. Lifestyles of individuals consist of various elements of daily living including consumption relating to nutrition, housing, mobility, consumer goods, leisure, and services. To illustrate the impact of household actions on climate

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change, this study focuses on **lifestyle carbon footprints: GHG emissions directly emitted and indirectly induced from the final consumption of households, excluding those induced by government consumption and capital formation such as infrastructure**. The consumption-based accounting adopted in this study attributes GHG emissions at production stages as indirect emissions caused by household consumption. This provides a different angle from the footprint of specific products, organisations, cities, or countries, which have been the foci of most footprint studies so far.

Analysis for this report set to establish global targets for lifestyle carbon footprints, to examine current consumption patterns and their impacts on footprints, and evaluate potential reduction impacts of low-carbon lifestyle options. The report proposes globally unified per capita targets for carbon footprint from household consumption in the years 2030, 2040 and 2050. Current average carbon footprints of Finland and Japan, as well as Brazil, India and China, are estimated focusing on the levels of physical consumption in order to be both comparable to global targets and compatible with household-level solutions. The report identifies potential options for reducing lifestyle carbon footprints and assesses the impact of such options for selected countries. The implications of the findings of these are then used to make recommendations on how to proceed towards lifestyles compatible with the 1.5°C target. The analysis captures a range of consumption contexts, and examines differences between the countries studied.

What we found - targets and gaps

The results highlight the massive gaps between current per capita footprints and targets. Estimates of current annual average lifestyle carbon footprints of the populations of countries we studied per person as of 2017 are: **Finland: 10.4 (tCO_2e), Japan: 7.6, China: 4.2, Brazil: 2.8, and India: 2.0**. In comparison, based on our review of the emission scenarios, this study proposes we need to aim for lifestyle carbon footprints targets of **2.5 (tCO_2e) in 2030, 1.4 by 2040, and 0.7 by 2050**. These targets are in line with the 1.5 °C aspirational target of the Paris Agreement and for global peaking of GHG emissions as soon as possible without relying on the extensive use of negative emission technologies. If negative emission technologies are considered, this raises the upper limits of the targets to 3.2, 2.2, and 1.5 tCO_2e per capita in 2030, 2040, and 2050, respectively – in other words their use greatly affects the target limits. In terms of the gaps between actual lifestyle footprints and the targets, footprints in developed countries need to be reduced by **80–93% by 2050, assuming that actions for a 58–76% (a 8-12% reduction every year from 2019 to 2030) start immediately to achieve the 2030 target. Even developing countries need to reduce footprints by 23–84%, depending on the country and the scenario, by 2050**.

Hotspots

A closer examination of lifestyle carbon footprints based on physical consumption units revealed several **hotspots**. Focusing efforts to change lifestyles in relation to these areas would yield the most benefits: **meat and dairy consumption, fossil-fuel based energy, car use and air travel**. The three domains these footprints occur in – nutrition, housing, and mobility – tend to have the largest impact (approximately 75%) on total lifestyle carbon footprints. Based on the domain-specific gap analysis with the targets, **the required footprint reductions in the case of developed countries are at least 47% in nutrition, 68% in housing, and 72% in mobility by 2030 and over 75% in nutrition, 93% in housing, and 96% in mobility by 2050**. Some of the hotspots such as car use and meat consumption are common among case countries, while others are country-specific, such as dairy consumption in Finland and fossil-fuel based electricity in Japan, suggesting we need to consider local contexts and tailor-made solutions.

Options with potential

The options with large emission reduction potentials as revealed in this study include: **car-free private travel and commuting, electric and hybrid cars, vehicle fuel efficiency improvement, ride sharing, living nearer workplaces and in smaller living spaces, renewable grid electricity and off-grid energy, heat pumps for temperature control, and vegetarian-vegan diets and substitute dairy products and red meat**. If these options are fully implemented they could reduce the footprint **of *each domain* by a few hundred kg to over a tonne annually**. The impacts we can expect naturally vary according to what extent we adopt the options – if the level is high, they could greatly contribute to achieving the 2030 1.5 degree target. This would require very ambitious levels of introduction in developed countries, such as over 75% for around 30 options.

The required level of reductions implies a radical rethinking of sustainability governance and business models.

Human carbon sinks – how they affect the targets

The various reduction scenarios we studied indicate that the target levels of reductions are sensitive to whether negative emission technologies such as carbon capture and storage (CCS) and bioenergy with carbon capture and storage (BECCS) are used. If use of such technologies is considered over the long term, the upper limits of the proposed targets are slightly eased (i.e., slightly easier to achieve), for 2030, 2040 and 2050 (in parentheses): 2.5 **(3.2)**, 1.4 **(2.2)**, and 0.7 **(1.5)** tCO_2e, respectively. However, the actual availability, feasibility and costs of these technologies are uncertain, thus solely relying on its assumed extensive and broad-ranging roll-out is a risky societal decision.

The takeaway – potential for adoption, and onus for action

This report represents one of the first of its kind in terms of proposing per capita footprint targets with explicit linkages to the Paris Agreement and assessing the gaps and solutions based on the physical amount of consumption across consumption domains. Its methods and approaches for highlighting the real impacts of current patterns of consumption and potential impacts of low-carbon lifestyles could be expanded for adoption in other dimensions and countries – such as to evaluate broader types of low-carbon lifestyle options, to facilitate action by stakeholders, or for creating interactive facilitative tools to assist stakeholders identify problem areas and solutions. The identified options could then be tested with real households, neighbourhoods and communities with government and private sector support to gauge the feasibility and acceptability of all solutions.

Although this study quantifies impacts of GHG emissions from perspective of lifestyles and consumption by households, it does not mean that individual households are solely responsible for reducing the footprints. The sheer magnitude of change required for a shift towards 1.5-degree lifestyles can only be achieved through a combination of system-wide changes and a groundswell of actions from individuals and households. As well as citizens beginning to adopt low-carbon lifestyles as soon as possible, **the required levels of reductions highlighted by this study, in some cases more than 90% based on current lifestyle carbon footprints, imply a radical rethink of sustainability governance and need for new business models, both of which have essential roles in shifting infrastructure, the economic system, and in shaping consumer choice and patterns. A massive undertaking is thus needed to develop capacities of all stakeholders in society, not only to understand the need for radical transformation going forward, but also to imagine alternatives to current ways of meeting needs, and to accept some difficult solutions that are inevitable if we are to become a sustainable civilisation**. The capacities of all stakeholders will need developing, both in developed and developing countries, which places an additional burden on the latter in enabling the major part of their populations to satisfy basic needs. Along with this challenge, however, comes opportunities, which this report identifies.


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1. Background

Despite the importance and quick mitigation potential of behaviour change, most policy approaches to climate change solutions have given it scant attention, choosing to focus instead on the application of technology (Creutzig et al. 2016). However, an increasing number of authoritative reports specifically highlight the considerable impacts of lifestyle changes, such as the Intergovernmental Panel on Climate Change (IPCC) Special Report on Global Warming of 1.5 °C, which underscores the urgency of finding solutions to climate change. The threat of the average global temperature rising by 1.5 °C between 2030 to 2052 if current trends continue, and by 3 °C by 2100 even with all countries' mitigation plans by 2030 combined paints a stark picture that delaying actions can only lead to increased costs, stranded assets, and reliance on technologies which have potential trade-offs with sustainability (IPCC 2018). This makes the case for redirecting lifestyles towards sustainability even more relevant. Climate science community considers the influence of demand-side actions as an element of pathways consistent with holding down the global temperature rise to below 1.5 °C, stating that behaviour and lifestyles changes, as well as culture, including consumption patterns and dietary changes can complement structural and technological changes (IPCC 2014a, IPCC 2018). Changing our lifestyles can bring about results relatively quickly, especially in consumption domains that are not locked into existing infrastructure (see, e.g., Lettenmeier, Laakso, and Toivio 2017; Salo and Nissinen 2017; Moore 2013).

The majority of existing emission scenarios for the 1.5 °C target still assume production-based measures and negative emission technologies as primary mitigation measures (Rockström et al. 2017; Rogelj et al. 2015). Mitigation pathway scenarios incorporating demand-side reduction measures have emerged recently but are still limited (Van Vuuren et al. 2018). On the other hand, existing consumption-focused literature provides quantification of the mitigation potentials of low-carbon lifestyles, but the reduction targets are not directly linked to a pathway leading towards achieving the temperature targets of the Paris Agreement (Jones and Kammen 2011; Vandenbergh et al. 2008; Dietz et al. 2009). There is therefore a gap in the literature in terms of highlighting the potential contribution of lifestyle changes and the level of required changes to meet the specific targets of the Paris Agreement.

Consumption-based Accounting and Planetary Boundaries

In this study, GHG emissions and reduction potentials are examined using consumption-based accounting rather than production-based accounting (also referred to as territorial-based accounting). **Production-based accounting covers only direct emissions from domestic production activities within the geographical boundaries** and offshore activities under the control of a country, and does not consider embodied emissions from international trade (Boitier 2012; Moore 2013). The limitations of this accounting include the possibility of carbon leakage due to international trade and the fact that it might mislead insights into mitigation efforts (Boitier 2012; Moore 2013). Conversely, **consumption-based accounting (carbon footprinting) covers both direct emissions and embedded emissions due to the production and distribution of products and**

services including imported ones, which reflects the global impacts of final consumption and lifestyles of individuals. This approach addresses the carbon leakage issue and promotes broader options for mitigation, while importantly also not burdening developing countries with excessive emission commitments (Peters and Hertwich 2008). In this study, the term 'carbon footprint' refers not only to CO_2 but also other greenhouse gases, thus is also sometimes referred to as 'greenhouse gas footprint'.

To date, study of carbon footprints has mostly concerned the impacts of specific products, activities, and final demand of countries (see Box "Footprints and Emissions"). Research into household consumption over the past few decades (see Tukker et al. 2010; Hertwich 2005) has generally been based on monetary estimations, and few studies have covered the broader perspective of lifestyles (Schanes, Giljum, and Hertwich 2016; Salo and Nissinen 2017) or looked at consumption patterns based on physical amounts such as food intake, mobility distance, and energy consumption (Girod and De Haan 2010; Barrett et al. 2002; Nissinen et al. 2007; Moore, Kissinger, and Rees 2013). This study estimates carbon footprints primarily based on physical consumption data, which can help elucidate where reductions can be made, such as through substitution between consumption modes and reduction of physical amounts.

In this report, the carbon footprint is linked to the concept of planetary boundaries (Rockström et al. 2009; Steffen et al. 2015), which are biophysical thresholds that once crossed lead the Earth irreversibly out of the Holocene and, in consequence, leave less space for human life. Several approaches for determining ecological boundaries for human activities were proposed in the 1990s, such as the environmental space concept (Opschoor and Reijnders 1991; Weterings and Opschoor 1992; Buitenkamp, Venner, and Wams 1992), the Factor 10 concept (Schmidt-Bleek 1993a, b), and the ecological footprint concept (Wackernagel and Rees 1998). The emerging concept of environmental footprints (Hoekstra and Wiedmann 2014) considers that environmental sustainability requires footprints to be kept below their maximum sustainable levels on a global scale. The lifestyle-related per-capita targets of footprints published for the ecological footprint (Moore 2013; Moore 2015) and the material footprint (Lettenmeier, Liedtke, and Rohn 2014) can be understood as an application of the planetary boundary concept at the level of individuals. Some research papers have proposed per-capita carbon emission or footprint targets based on planetary boundaries (Nykvist et al. 2013; Dao et al. 2015), but have done so only at a macro country level, and do not state quantities or demarcate the role of lifestyles and lifestyle-related pathways. Building on these previous efforts, this study establishes per-capita, consumption-based targets of GHG emissions compatible with the Paris Agreement temperature goals, and assumes an equitable and global long-term target of 'carbon footprint per capita', which links in with the concept of "contraction and convergence" (Meyer 2000).

The challenges in establishing long-term per capita carbon targets lie in the nature of balancing GHG emissions and sinks. Unlike the ecological footprint that can, in principle, be directly compared with biocapacity at any point in the future, establishing a carbon footprint target requires a dynamic assumption of emission reductions toward the future. Proposing carbon budgets places limits on the amount of global emissions in order to stabilise the concentration of GHGs in the atmosphere; a number of published emission scenarios suggest pathways for reducing total emissions at the global level, such as in the United Nations Environment Programme Emissions Gap Report (UNEP 2016). The proposed per-capita carbon footprint targets in this study assume the targets will dynamically shrink towards the future, based on the selected existing emission scenarios.

Lifestyle Carbon Footprints

'Carbon footprint' refers to GHG emissions directly and indirectly caused by activities or products throughout their lifecycle, from a consumption perspective, and can be calculated for products as well as daily activities of individuals or organisations (Wiedmann and Minx 2008). The focus of this study is on daily activities of individuals determined by the choices they make on ways of living. In this study, **'lifestyle carbon footprint' is defined as the GHG emissions directly emitted and indirectly induced from household consumption, excluding those induced by government consumption and capital formation**.

GHGs covered

As the Paris Agreement does not limit the GHGs to be reduced, non-CO_2 emissions also need to be considered due to their higher global warming potential and related lifestyle and consumption choices. Therefore, this study also considers emissions of methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6), as in most global carbon footprint analysis literature and the UNEP Emissions Gap Report 2018 (UNEP 2018). This study estimates carbon footprints using carbon intensity data covering these six gas species if the types are explicitly mentioned, or GHG intensity data rather than CO_2 data if not.

Structure of the Report

This report fills a gap in the existing research by establishing global targets for lifestyle carbon footprints, examining current consumption patterns and their impacts on footprints, and evaluating potential reduction impacts of low-carbon lifestyle options. Following this background chapter, Chapter 2 proposes globally unified per capita targets for the carbon footprint from household consumption for the years 2030, 2040 and 2050. In Chapter 3, current average carbon footprints of Finland and Japan, as well as Brazil, India and China, are estimated focusing on the comparison of the level of physical consumption in order to be both comparable to global targets and compatible with household-level solutions. Chapter 4 identifies potential options for reducing lifestyle carbon footprints on the basis of the literature and assesses the impact of such options in Finnish and Japanese contexts. It concludes with suggestions and implications in terms of how to proceed towards lifestyles compatible with 1.5 °C target. The case countries were selected to capture a range of different consumption contexts, including capturing differences between developed and developing countries. As the report only covers the countries given above, similar studies can be expanded to other countries using the methodology, data sources, and results of estimation that are detailed in Annexes A to F.

Footprints and Emissions – Comparison of boundaries and scopes

Different boundaries and scopes are used to measure GHGs per capita, as below:

Production-based emissions

GHGs directly emitted from households, governments, and private sector activities within the territorial boundary of a country or city, excluding indirect emissions caused by the consumption of products and services. This measurement is used in national GHG inventories and target setting.

Footprint of products

GHGs directly and indirectly emitted from the production, distribution, use, and disposal of products, including those embedded in imported parts and products. This type of measurement is used for carbon footprint labelling and comparison of two or more types of options of products or processes, and is typically based on a bottom-up process analysis of life cycle assessment (LCA). The specification for this type of measurement is also published as International Organization for Standardization (ISO) 14067 (ISO 2018a).

Organisational footprint

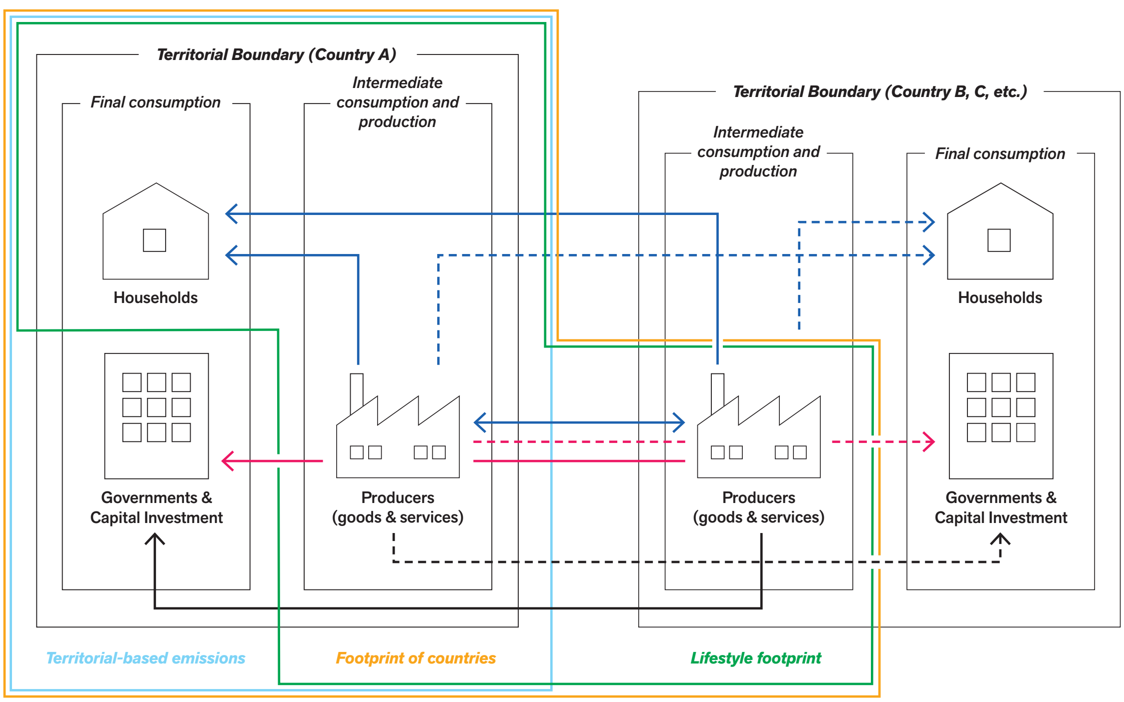
GHGs emitted from direct activities of organisations (scope 1), sourcing of energy (scope 2), and other indirect emissions through value chains including production, distribution, use, and disposal of products sold (scope 3). The standards for this type of measurement include ISO 14064-1 (ISO 2018b) and GHG Protocol (Greenhouse Gas Protocol 2011), and this measurement is typically based on the hybrid method of bottom-up process analysis LCA and top-down input–output (I/O) analysis–based estimation.

Footprint of countries or cities

GHGs directly emitted from activities of households and governments located in a country or city and those indirectly emitted from the final demands of those actors and capital investment including production, distribution, use, and disposal of purchased products and services including those embedded in trades. This type of measurement is typically based on the top-down I/O analysis method. Examples of estimation are Environmental Footprint Explorers (Norwegian University of Science and Technology 2018) for countries and C40 (C40 Cities Climate Leadership Group 2018) for cities.

This study focuses on the lifestyle carbon footprint, meaning the carbon footprint of an average household in a country, including its direct emissions from the use of fuels and indirect emissions embedded in products and services purchased (Figure 1.1). This can be considered as a household version of the organisational carbon footprint or household demand part of the footprint of countries or cities.

Figure 1.1 Comparison of the boundary of GHG emission and footprint




2

2. Long-term Targets of Lifestyle Carbon Footprints

2.1. Temperature Targets in the Paris Agreement

The Paris Agreement in 2015 secured a clear global commitment to hold the global average temperature increase well within 2 °C above pre-industrial levels as well as pursue efforts to limit it to 1.5 °C (UNFCCC 2015). In setting this target, a peak in emissions is assumed to occur as soon as possible, after which emissions are to rapidly drop, to achieve a society based on net-zero emissions in the latter half of the 21st century. For the below-2 °C target, global emissions need to be limited to 40 gigatonnes in 2030, according to a UN decision based on the Paris Agreement (UNFCCC 2015) – and the decision also expressed the concern that this limit cannot be reached by the present Intended Nationally Determined Contributions (INDCs) of countries, which result in 55 Gt in 2030. This implies that emissions need to be reduced more drastically starting from now to limit the increase to below 1.5 °C.

The 2 °C and 1.5 °C targets are based on long-running scientific research on GHG emissions projection, climate modelling, and climate change impacts on Earth and humanity. Research activities on future emissions and their impact on climate, often utilising integrated assessment models (IAMs), provide us with projections of future global GHG emissions levels under different sets of assumptions and the maximum amount of GHGs allowed to remain in the atmosphere for a certain target. These projections, also known as "mitigation pathways", are frequently accompanied by measures to realise them. Such research is used by the IPCC as reference in preparing regular IPCC Assessment Reports (AR) on the state of knowledge on climate change. The Fifth Assessment Report (AR5), published in 2014, focuses on the global target of keeping the global average temperature increase below 2 °C as established by the 2010 Cancun Agreement (IPCC 2014a). However, results of research activities on climate change impact have shown that a 2 °C target may not forestall existential risks to ecosystems, such as small islands, or extreme weather events (IPCC 2014b). Due to these risks, the global community was urged to be more ambitious and aim for the below-1.5 °C aspirational target.

Research findings on mitigation pathways to meet the 1.5 °C target were limited until the parties invited the IPCC to produce a special report on the 1.5 °C target and its related emissions pathways (UNFCCC 2015). To prepare for this report, the IPCC opened a call for submissions of new assessments on scenario pathways to limit warming to 1.5 °C and published the IPCC SR1.5 Scenario Database, after which the special report was published, in October 2018. The IPCC Special Report focused on the impacts of global warming of 1.5 °C and related global GHG emission pathways in the context of strengthening mitigation actions (IPCC 2018).

Despite the scarcity of research specifically aimed at limiting global warming below 1.5 °C, it is important to note that 1.5 °C pathways are interconnected with 2 °C pathways as they are likely to be further iterations of 2 °C pathways assessments with more stringent mitigation measures. Hence, in 1.5 °C scenarios, meeting the 2 °C target is projected with higher probability. In this report, we aim to illustrate the per capita GHG footprint budget for the final consumption of households for the 1.5 °C target under the Paris Agreement as a main scenario and also for the 2 °C target for indicating a range of targets.

2.2. Identifying Mitigation Pathways towards the Targets

In this report, we illustrate our proposed targets for lifestyle carbon footprints to meet the Paris Agreement targets based on total carbon footprint expressed in emission budget pathways found in the literature. We shortlisted pathways from publicly available studies that are compatible with the 2 and 1.5 °C targets. As assumptions on utilisation of human carbon sink technologies is a key determinant for mitigation pathways to meet the targets, we also considered both cases of reliance and non-reliance on human carbon sinks. We reviewed scenarios contained in the IPCC AR5 Scenario Database[1], the United Nations Environment Programme Emissions Gap Report 2017 (UNEP 2017), as well as individual peer-reviewed papers in academic journals published subsequently thereto, and screened them based on the following criteria:

- Consists of a pathway to keep the global average temperature increase below 2 °C with at least 66% probability, or below 1.5 °C with at least 50% probability.
- Provides a quantified estimate of a carbon budget on a time scale up to year 2100, information on the type of model, and the baseline scenario.
- Aims to limit atmospheric GHG concentration at 430–480 parts per million (ppm) CO_2eq for 2 °C target and 430–450 ppm CO_2eq for 1.5 °C target (in 2100).
- Estimates a cumulative carbon budget at 350–950 GtCO_2 for 2 °C target and less than 350 GtCO_2 for 1.5 °C target (2011–2100).
- Covers CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6 gases in its estimation.
- Explains the assumptions of "human carbon sink" utilisation (also known as negative emissions or CO_2 removal technologies, see Annex A for more information).
- If formulated before the year 2015, assumes a global climate policy commitment is secured in the near future to reduce GHG emissions and limit the increase in the global average temperature (as represented by the Paris Agreement).

From our literature review and screening study, we derived two important findings.

First, prior to the open call for scenarios for the IPCC Special Report on Global Warming of 1.5 °C, only a limited number of papers reported results of modelling analysis for pathways compatible with the 1.5 °C target. This is reflected in the coverage of the UNEP Emissions Gap Reports for 2016 and 2017 (UNEP 2016, 2017), which only included one study for 1.5 °C emissions budget analysis. The recently published IPCC Special Report on Global Warming of 1.5 °C: Summary for Policymakers (IPCC 2018) attracted new research findings and was able to provide global net emissions pathways (anthropogenic emissions reduced by anthropogenic removals) and four "illustrative model pathways", produced based on assessing new scenarios and studies. The same database of scenarios was used by the 2018 Emissions Gap Report (UNEP 2018). The IPCC pathways illustrate characteristics of four potential mitigation strategies which applied different combinations of assumptions on technological innovation level, societal and consumption changes, and use of negative emissions technologies, based on the collected scenarios (IPCC 2018).

Second, most of the 1.5 °C pathways in the AR5 database indicate strong reliance on human carbon sink technologies[2] (Rockström et al. 2017; Rogelj et al. 2015), but more recent scenarios used by the IPCC Special Report on Global Warming of 1.5 °C rely on them to a lesser extent. Research has argued that renewable energies and energy demand reduction can replace them (Van Vuuren et al. 2007) while another study estimated they can only be substituted with deep emission reductions within the years 2020 to 2030 while increasing energy efficiency and the use of direct air carbon capture and storage (Rockström et al. 2017). On the other hand, for the 2 °C target, assumptions on the use of human carbon sinks are more diverse; we were able to find pathways both with (Rogelj et al. 2011) and without human carbon sinks (Blanford et al. 2014; Fuss et al. 2014; Magné, Kypreos, and Turton 2010). For this target, CCS has been promoted due to its potential to increase cost-effectiveness of global mitigation (Blanford et al. 2014; Fuss et al. 2014; Magné, Kypreos, and Turton 2010).

The shortlist we compiled contains five pathway scenarios, which we renamed for use in this report (Table 2.1); the names are prefixed with "1.5–" or "2.0–" corresponding to the temperature targets they are comparable to, and suffixed with "–S" (for "sink"), for scenarios that rely on human carbon sink technologies, or "–D" (for "demand") for scenarios that emphasise the use of demand-side measures instead. Land use, land use change, and forestry (LULUCF) is excluded from the selected mitigation scenarios. More details about the methodology for screening emissions scenarios and details of each shortlisted scenario can be found in Annex A.

1 The Integrated Assessment Modeling Consortium (IAMC) 1.5°C Scenario Explorer, which compiles pathways underpinning the IPCC Special Report on Global Warming of 1.5°C, was not yet available to the public as of the timing of the review of scenarios in this study.

2 We observed a number of human carbon sink technologies in the scenarios, including carbon capture and storage technologies for fossil fuel power plants (fossil CCS), bioenergy combined with CCS (BECCS), and direct air CCS.

Table 2.1. Shortlisted scenarios with reliance on carbon sinks for emissions budget illustration

Scenario	Description	Reference
1.5S: 1.5 °C with Human Carbon Sink Scenario	Pathway to the 2 °C target with 75% probability and the 1.5 °C target with 50% probability, considering the use of all sinks starting before year 2050	Rockström et al. (2017)
2S: 2 °C with Human Carbon Sink Scenario	Pathway to the 2 °C target with more than 66% probability, considering the use of CCS technologies	Rogelj et al. (2011)

Table 2.2 Shortlisted scenarios with demand-side measures for emissions budget illustration

Scenario	Description	Reference
1.5D (a): 1.5 °C with Demand-side Measure Scenario	Pathway to the 1.5 °C target with 60% probability, without the use of CCS	"A2" scenario from (Ranger et al. 2012)
1.5D (b): 1.5 °C with Demand-side Measure Scenario	Pathway to 1.5 °C target with stringent measures to reduce end-of-pipe emissions and non-CO_2 GHG emissions	"Low Non-CO_2" scenario from (Van Vuuren et al. 2018)
1.5D (c): 1.5 °C with Demand-side Measure Scenario	Pathway to 1.5 °C target with land sector sequestration, increased efficiency, renewable electricity, agricultural intensification, low non-CO_2 emissions, lifestyle changes, and low population growth	"All Options" scenario from (Van Vuuren et al. 2018)

It should be noted that the above scenarios were shortlisted from those available at the time of the literature review for the final draft of this report. Using the above scenarios, we were able to choose one representation of a lifestyle carbon footprint target compatible with the Paris Agreement (see section 2.3 below).

2.3. Exploring Targets of Lifestyle Carbon Footprints

The GHG emission targets at the global level identified in the previous section are converted into per capita carbon footprint targets from household consumption in this section so that we can see how they affect household consumption and lifestyles.

In this study, per-capita carbon footprint targets are assumed to be globally unified by 2030. Since climate change is a global scale phenomenon, the assumption made in this study is that everyone living in the same year in the world, regardless of age, location, and any other status, would have an identical carbon footprint target at the national average level. The approach in this study partly adopts the concept of "contraction and convergence" proposed by Meyer (2000), but using more simplified assumptions. "Contraction and convergence" suggests that global greenhouse gas emissions should be reduced towards an equal per-capita level across countries in the long run (e.g., by 2020, 2030, or 2050), while assuming different pathways of the reduction from current per-capita emission levels towards the target for each region. Its focus is on the convergence of per-capita emissions of countries rather than footprint of individual households. However, this study focuses on the footprints of household consumption and globally unified targets by 2030, 2040, and 2050. Therefore, rather than trying to precisely simulate the pathways of reduction for each country, we calculate the per-capita reference target based on the means of the selected representative emission scenarios discussed in the previous section.

In order to do this, the total GHG emission limit per year was divided by the estimated population of the reference year based on the median projection of the 2017 Revision of the World Population Prospects (United Nations 2017), thus the per-capita carbon footprint targets in this study use the formula below:

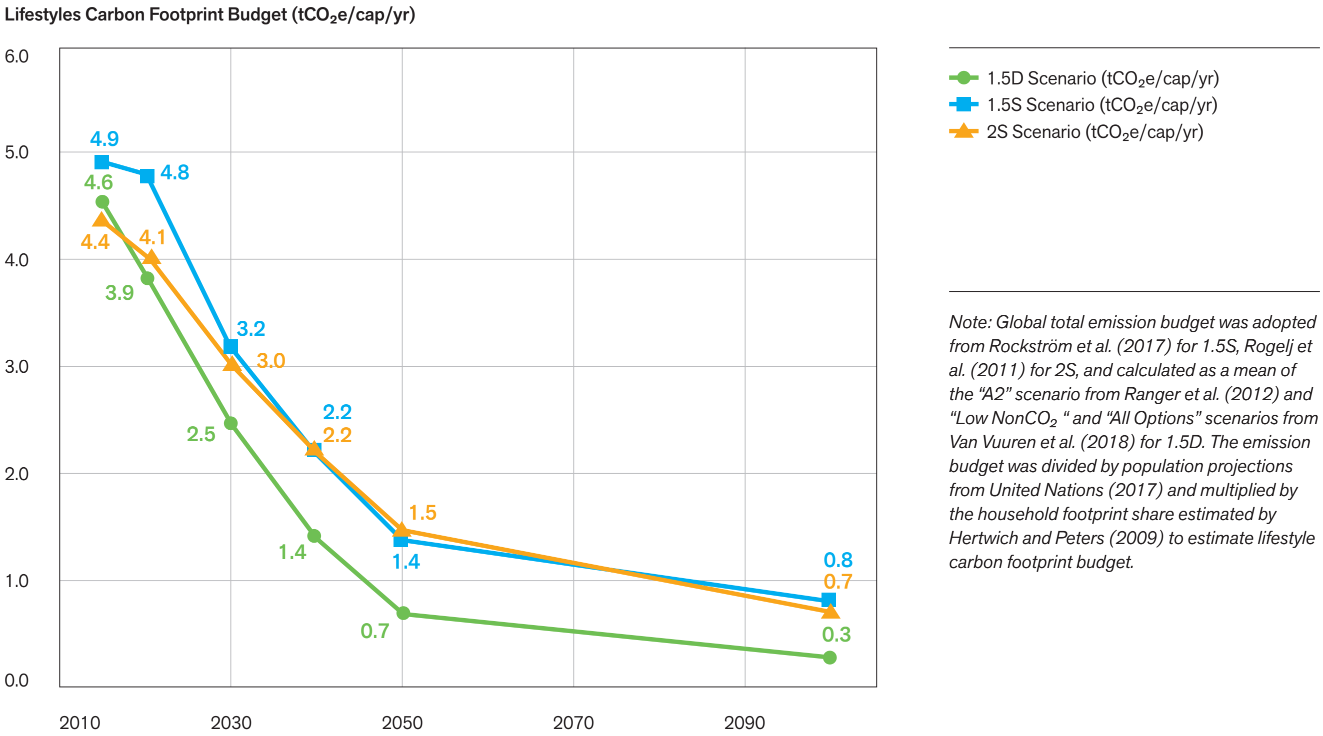
Per-capita annual carbon footprint target
= Annual global emission target / predicted world population

Then, to examine the carbon footprint directly related to lifestyles of individuals in detail, this study proposes targets of carbon footprints attributed to household final demand (lifestyle carbon footprints) based on the results of the existing I/O analyses of multi-country carbon footprint estimates. Of these, Hertwich and Peters (2009) cover 73 countries and 14 aggregated regions for 2001 using the Global Trade Analysis Project (GTAP) database, giving an average share of carbon footprint by household consumption at the global level of 72%. Another study, Ivanova et al. (2016), gives an estimate of 65% ± 7% (mean ± standard deviation). Although the latter is more recent (2007), it is based on a more limited data pool of only 43 countries (EXIOBASE database), biased towards the EU, thus we adopted the Hertwich and Peters (2009) estimate of 72% and calculate carbon footprint targets using the formula below:

Per-capita annual lifestyle carbon footprint target
= Per-capita annual carbon footprint target x 0.72

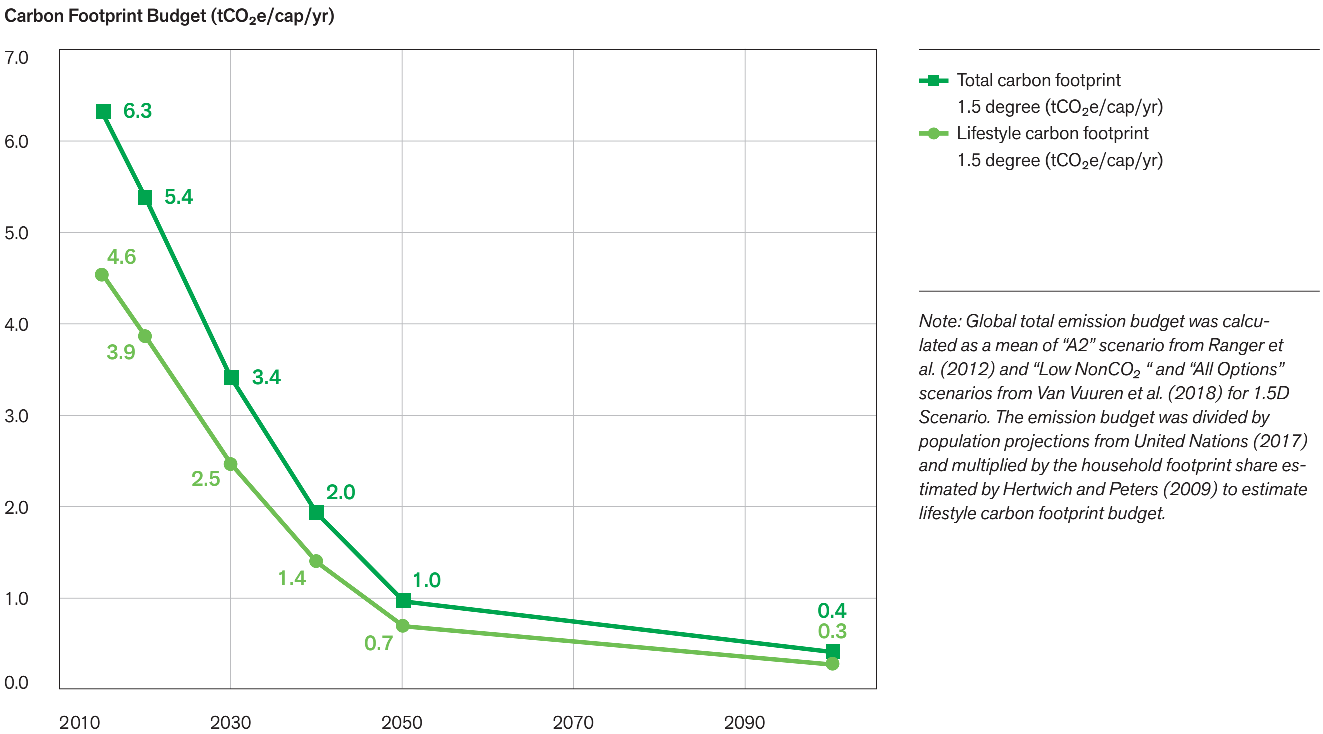
It should be noted that the above estimates are based on the limited publicly available household footprint share estimations, which may involve levels of uncertainty. Also, the assumed share in the present study is based on a mean of the countries included in the aforementioned study, which does not consider the variation among countries, such as those due the economic structure and the the level of per-capita carbon footprints. Furthermore, the household footprint shares in this study are fixed

Figure 2.1. Lifestyle carbon footprint budget from shortlisted mitigation pathways



Note: Global total emission budget was adopted from Rockström et al. (2017) for 1.5S, Rogelj et al. (2011) for 2S, and calculated as a mean of the "A2" scenario from Ranger et al. (2012) and "Low NonCO$_2$ " and "All Options" scenarios from Van Vuuren et al. (2018) for 1.5D. The emission budget was divided by population projections from United Nations (2017) and multiplied by the household footprint share estimated by Hertwich and Peters (2009) to estimate lifestyle carbon footprint budget.

Figure 2.2. Lifestyle carbon footprint budget comparable with 1.5 °C target (without or with less use of CCS)



Note: Global total emission budget was calculated as a mean of "A2" scenario from Ranger et al. (2012) and "Low NonCO$_2$ " and "All Options" scenarios from Van Vuuren et al. (2018) for 1.5D Scenario. The emission budget was divided by population projections from United Nations (2017) and multiplied by the household footprint share estimated by Hertwich and Peters (2009) to estimate lifestyle carbon footprint budget.

towards the future, without assuming variations in the allocation of carbon footprints between household, government, and capital investment.

It also needs to be noted that the three representative scenarios (1.5D, 1.5S, and 2S scenarios) were selected among those publicly available at the time this report was drafted. Representative scenarios for the 1.5 °C target (1.5D and 1.5S) incorporated in this study were used as references for illustrative model pathways included in the IPCC Special Report on Global Warming of 1.5 °C. Other scenarios that have come to light since our drafting could therefore be incorporated into future research. Further, the population estimates of the three scenarios were unified to the UN projection, which may not be exactly consistent with the socio-economic framework of each scenario due to the mixing of different scenarios because population estimates used in the emission scenarios are generally not made publicly available.

As regards target calculations, this study proposes a unified level of per-capita footprints for 2030, 2040, and 2050, and did not consider detailed pathways from the current footprints, nor whether emission allowances were equitable in terms of historical emissions, or climatic or other natural conditions of the countries concerned. Instead, the proposed targets are based on a simplified calculation using population projections and household footprint share, and thus do not consider dynamic aspects of modeling of consumer lifestyles and scenario analysis, which could be further researched in the future. Nevertheless, elucidating a globally unified lifestyle carbon target would help in indicating the average levels of reductions needed.

The targets of lifestyle carbon footprints (carbon footprints from households) in the five shortlisted scenarios we explored are summarised in Figure 2.1–2.2 and Table 2.3. In terms of all GHGs, the ranges of the estimated lifestyle carbon footprint targets for 2030, 2040, and 2050 are respectively 3.2–2.5, 2.2–1.4, and 1.5–0.7 tCO_2e per capita. The ranges overlap due to different assumptions regarding negative emission technologies and temperature targets. The selection of targets between the lower and higher ends depends on assumed long-term availability of human carbon sinks or negative emissions technologies, such as BECCS, and the selection of the global average temperature targets, either 1.5 °C or 2.0 °C.

Targets for lifestyle carbon footprints comparable with the 1.5 °C aspirational target of the Paris Agreement is 2.5 and 0.7 tCO_2e per capita for 2030 and 2050.

Table 2.3. Lifestyle carbon footprint targets from shortlisted mitigation pathways

Scenario	Per capita target of lifestyle carbon footprint (Per capita target of total carbon footprint)					
	2015	2020	2030	2040	2050	2100
1.5S	4.9 (6.8)	4.8 (6.7)	3.2 (4.4)	2.2 (3.1)	1.4 (1.9)	0.8 (1.1)
2S	4.4 (6.1)	4.1 (5.6)	3.0 (4.2)	2.2 (3.0)	1.5 (2.1)	0.7 (1.0)
1.5D (a)	4.7 (6.6)	3.7 (5.1)	2.3 (3.1)	1.4 (1.9)	0.9 (1.2)	0.1 (0.2)
1.5D (b)	4.4 (6.1)	4.1 (5.6)	2.7 (3.7)	1.4 (2.0)	0.5 (0.7)	0.4 (0.5)
1.5D (c)	–	–	–	–	0.7 (1.0)	0.3 (0.4)

Note: Global total emission scenarios are adopted from Rockström et al. (2017) for 1.5S, Rogelj et al. (2011) for 2S, "A2" scenario from Ranger et al. (2012) for 1.5D (a), "Low NonCO$_2$" scenarios from Van Vuuren et al. (2018) for 1.5D (b), and "All Options" scenarios from Van Vuuren et al. (2018) for 1.5D (c). The emission budget was divided by population projections from United Nations (2017) and multiplied by the household footprint share estimated by Hertwich and Peters (2009) to estimate lifestyle carbon footprint budget.


3

3. Overview of Current Lifestyle Carbon Footprints

3.1. Estimating Current Lifestyle Carbon Footprints

This study set out to measure lifestyle carbon footprints resulting from the GHG emissions directly emitted and indirectly induced from all aspects of household consumption (goods and services). The OECD defines household consumption as the "consumption of goods and services by households", and refers to their choises and actions related from selection to disposal of products and services (OECD 2002). Lifestyle carbon footprints include embedded and indirect emissions, i.e., those resulting from intermediate consumption during production induced by household final demand, but direct and indirect emissions and footprints caused by public sector and capital investment were not considered. This approach allows us to have a clear focus on the lifestyles that lead to household emissions footprints, which result from individual choices and partly due to lock-in effects of present day sociotechnical systems (Akenji and Chen 2016).

This study focuses on footprints of average Finnish and Japanese consumers as main case countries, with 2017 as the reference year, but also covers those of Brazil, China, and India as emerging countries in order to capture a range of different consumption contexts and highlight differences between developed and developing countries.

Lifestyle Domains Covered in the Estimation

This study classifies household resource consumption into six domains, based on previous studies (e.g., Michaelis and Lorek 2004; Tukker et al. 2006; Kotakorpi, Lähteenoja, and Lettenmeier 2008; Seppälä et al. 2011; Lettenmeier, Liedtke, and Rohn 2014), as below:

1. Nutrition: intake of all foodstuffs and beverages consumed at home and outside the home, e.g., vegetable and fruit, meat, fish, dairy, cereal, alcohol and nonalcoholic beverages.[3]

2. Housing: housing infrastructure and supply of utilities, e.g., construction, maintenance, energy use and water use.

3. Mobility: use of owned transport equipment and transportation services for commuting, leisure, and other personal purposes, e.g., cars, motorbikes, public transport, air travel, bicycles.[4]

4. Consumer goods: goods and materials purchased by households for personal use not covered by other domains, e.g., home appliances, clothes, furniture, daily consumer goods.[5]

5. Leisure: leisure activities performed outside of the home, e.g., sports, culture, entertainment, hotel services.[6]

6. Services: services for personal purposes, e.g., insurance, communication and information, ceremonies, cleaning and public baths, public services.[7]

3 Direct emissions from cooking at home are included under housing, whereas emissions from operation of restaurants are included under leisure.

4 Emissions from business purpose trips are included under respective domains of the products or services supplied.

5 Direct emissions from electricity and fuels used by consumer goods are included under housing.

6 Emissions from ingredients of food taken out of home are included in nutrition, whereas direct emissions from leisure performed at home are included in housing.

7 Public services covered by government expenditure are excluded from lifestyle carbon footprints.

The Steps of Lifestyle Carbon Footprint Estimation

The current carbon footprint is calculated and analysed on a per-person per-year basis, with 2017 as the reference year. In the absence of specific data, that from the latest available year was used, assuming that the level of consumption or intensity was constant over these years. The boundary of the estimation covers "from cradle to grave" regarding the consumption of goods and services by households, including resource extraction, material processing, manufacturing, delivery, retail, use, and disposal, but excluding land use, land use change, and forestry (LULUCF). If the scope of the GHG intensity data was not compatible with this boundary setting, supplementary data was used to increase the coverage of the estimation wherever possible.

The estimation of the footprints generally uses bottom-up and top-down methods, and each method has strengths and weaknesses. The top-down method, using I/O analysis, has better coverage, its estimation is based on monetary units of expenditure but not physical units, and the results are sensitive to the selection of I/O models. In contrast, the bottom-up method, using LCI databases calculated from the analysis of typical processes, can more precisely estimate products or services based on physical units, but has a weakness as the coverage of items cannot be increased. This study mainly uses the bottom-up approach, combining micro-level carbon footprint data with national statistical data for major domains and items, with use of the top-down approach to increase the coverage of estimates. For the three major domains (nutrition, housing, mobility), it uses physical units (e.g., weights of food, distances covered of transport) rather than amounts of expenditure. This makes it easier to link this study with the actions needed to be taken at the household level. The top-down methods were mostly used for other domains (goods, leisure and services) and minor items in order to improve the coverage of the estimation. The approach included the following steps:

1. Collecting national data (statistics) for each country to define the average consumption for the six consumption domains in units of food weight (kg), transport distance (passenger-km), energy consumption from housing (kWh), housing space (m^2), and product or service expenditure (Euro or Japanese Yen).

2. Obtaining carbon intensity values of goods and activities from lifecycle inventory (LCI) databases or other public or internal data. For Finland, the carbon intensities are mainly from the Ecoinvent database (Wernet et al. 2016). I/O analysis–based estimations are also used for consumer goods, leisure, and services (Seppälä et al. 2009) to increase estimation coverage. For Japan, country-specific bottom-up LCI data, e.g., MOEJ (Ministry of the Environment, Japan 2016) and JEMAI (Japan Environmental Management Association For Industry 2012), for food, housing, and mobility as Ecoinvent does not cover Japan-specific data. A top-down I/O analysis–based database using the Global Link Input-Output (GLIO) model (Nansai et al. 2012) was used for other domains and items in order to increase estimation coverage (see Annex B for country-specific methodology).

3. Calculating the carbon footprint for each item (product or service) by multiplying amounts by the most appropriate carbon intensity value (Figure 3.1). Some variations exist among the case countries, due to differences in consumption data for items (see Annex B).

4. Summing up the resulting carbon footprint of single items to components (e.g., meat, cereals, vegetables) and domains of consumption (six domains: nutrition, housing, mobility, consumer goods, leisure, and services). The number of components among the case countries is unified wherever possible to improve comparability.

5. Visualising estimated lifestyle carbon footprints for domains as skyline charts and doughnut charts to highlight hot-spots and compare amounts of physical consumption and carbon footprints.

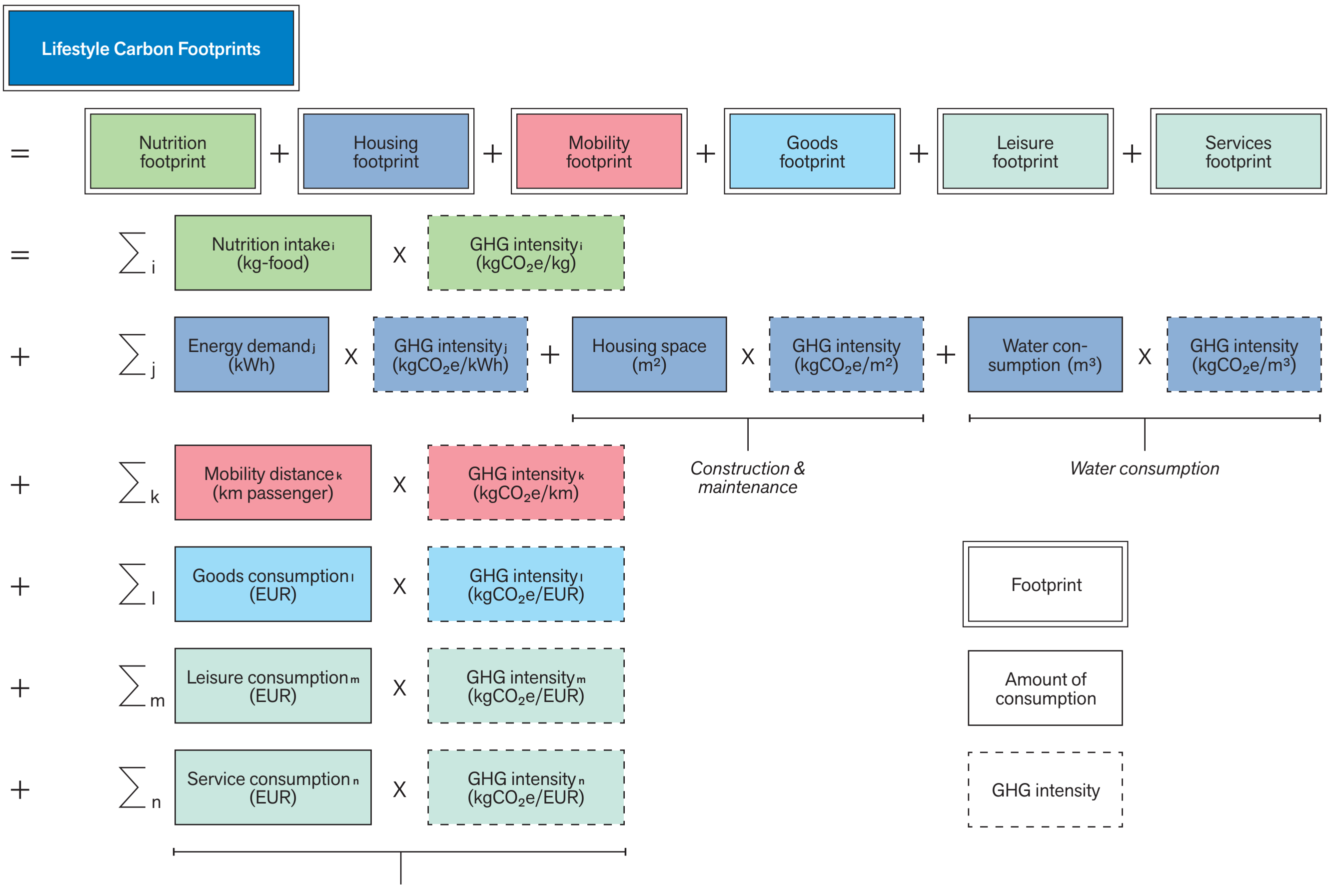
6. Expressing long-term targets established in the previous chapter via graphs to identify gaps in lifestyle carbon footprints and levels of reduction required based on the 2030 and 2050 targets (1.5 °C without or with reduced use of CCS). The total target lifestyle carbon footprints were allocated to each domain based on the analysis of the anonymised microdata of the 2004 National Survey of Family Income and Expenditure (NSFIE) (Ministry of Internal Affairs and Communications, Japan 2004) provided by the National Statistics Center (see Annex D for methodology details).

The results of the calculation were summed up in tables and figures to compare the carbon intensities and carbon footprints of different countries, consumption domains and components, and are discussed and analysed in the following sections (see Annex B for detailed calculation methods, data sources, and country-specific methodology and Annex C for detailed tables of the results).

This study, like all scientific studies, has certain limitations. First, as it is a near impossibility to get coverage for every activity, data for this analysis may not cover some minor activities in some domains due to the limitation of the bottom-up LCA data primarily used in this study. Second, since the amount of consumption in this study was estimated using data available from each country, it is subject to the variable quality of data from various national and other official statistics, due to different methodologies used by agencies producing statistics. Third, the fact that in some cases where data for the reference year (2017) was unavailable, statistics were drawn from the next closest years for which data was available[8]. Furthermore, the footprint targets for 2030 and 2050 allocated to each domain should be considered as only indicative, since they were based on the

8 Food consumption data used for Brazil, China and India is based on the latest Food and Agriculture organisation (2017) "FAOSTAT: Food Balance Sheet" (data from 2013). It is noted that consumption amounts for individual food products might be over- or underestimated compared to present consumption. Carbon footprint estimates used for consumer goods, and leisure and services in these countries is based on the study of Hertwitch and Peters (2009). It should be noted that the footprints for these domains might be over- or underestimated due to the limited availability of more recent data.

Figure 3.1. Estimation of lifestyle carbon footprints across domains



Notes: Units of currency should be Euro, Japanese Yen, or other local currencies.

analysis of microdata in Japan. In this study, carbon footprint targets are allocated to each domain based on the trends of footprint share among different households in the cross-sectional data, but do not consider future dynamic changes in technology or other factors, which could be the subject of future research.

Other limitations are also related to the data sources, such as slight variation in boundaries and assumptions of carbon intensity data due to the nature of bottom-up LCA. We selected the data sources that are mostly compatible with the boundary of this study, but there may be slight differences in boundaries and assumptions or, in some cases, the detailed information was not clearly indicated in the databases. For example, LULUCF is excluded from most carbon intensity data, but is not always explicit in every single item in the LCA databases. Furthermore, country specificity of carbon intensity was not always satisfied. We selected country specific intensity data whenever available, and used rest of the world (RoW) or other data otherwise. The study also assumed the intensity of imported products was the same as for domestic products[9], which is expected to cause minor errors in the current footprint estimates. Errors in footprint estimation is a common issue, as even top-down I/O analysis–based estimations involve uncertainty due to model selection and sectoral aggregation, and different models tend to have substantially different estimation results (Owen et al. 2014; Arto, Rueda-Cantuche, and Peters 2014; Steen-Olsen et al. 2014). For more details, please see Tables B.2-2 and B.3-2 in Annex B.

Finally, as determining footprints of consumption of public services is not straightforward since they are partly paid for by households but are also subsidised or operated by governments, this study considered public services charged to individuals, for Japan and Finland. Infrastructure is excluded because it is not directly linked to the final demand of households in the data used. This study also excludes systemic interactions between household consumption and government-capital investments, even though they are linked on a deeper level (see also Lettenmeier, Liedtke, and Rohn 2014), which is a matter for future research.

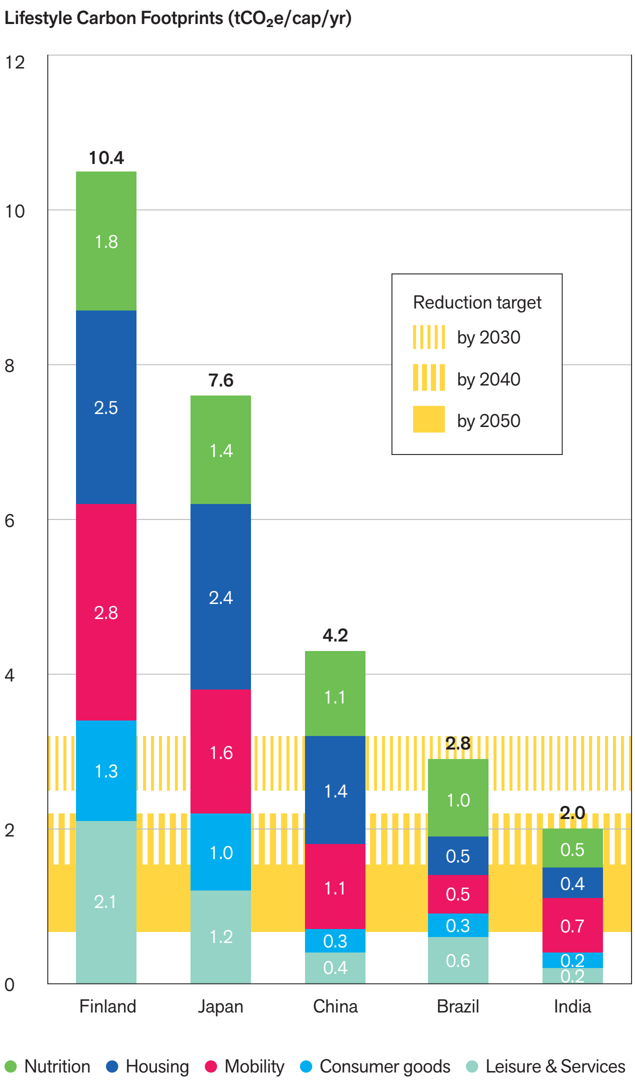
Considering these limitations, the individual intensity data of a specific item may not be directly comparable between countries. This study compares inter-country consumption, footprint, and intensity at the component level or domain level to reduce errors. The focus of this study is to illustrate the overall picture of GHG emissions brought about by lifestyles rather than the footprint of particular products or services.

9 Except for the top-down based estimates based on the intensity data from the globally-linked input output (GLIO) model in Japan. In Finland, top-down based (ENVIMAT) model applied a hybrid approach, where a part of the imported-related data was replaced by data for specific products obtained from the global databases. Global data coverage of imports was 88%. The missing volume mostly related to consumer goods and the missing intensities were assessed with domestic emission factors.

3.2. Comparing Lifestyle Carbon Footprints

Total average lifestyle carbon footprints vary considerably – Finland has the highest at 10.4 tonnes (tCO_2e) per year, then Japan at 7.6, China at 4.2, Brazil at 2.8, and India at 2.0, as shown in Figure 3.2. Compared with the upper and lower limits of GHG emission targets proposed for 2030 (2.5–3.2 tonnes per capita in terms of all GHGs, see Section 2.3), Finland and Japan far exceed the targets, China overshoots moderately, and Brazil slightly. As a result, GHG emissions of countries need to drop by the following percentages: Finland 69–76%, Japan 58–67%, China 25–41%, Brazil up to 11% by 2030. India currently already satisfies the emission targets for 2030. The GHG emission target ("1.5D" target) proposed for 2050 (0.7 tonnes per capita in terms of all GHGs) is exceeded in all case countries. Notably, large GHG emission reductions of 86–93% and 80–91% are

Figure 3.2. Carbon footprint and its breakdown between consumption domains and globally unified targets for the lifestyle carbon footprints



Note: Average lifestyle carbon footprint of country estimated as of 2017. The lower and upper limits of horizontal lines indicate 1.5D (1.5 °C without/less use of CCS) and 2S (2 °C with CCS) targets, respectively.

needed in Finland and Japan, respectively, but reductions are also needed in China, Brazil and India too – 65–84%, 47–75% and 23–64%, respectively.

Out of the consumption domains considered, the triple domains of nutrition, housing and mobility tend to have the largest impact (three-quarters, or 75 ±8%) on total carbon footprint. In Finland, mobility and housing contribute the biggest share of the carbon footprint (27–24%: 2.8–2.5 tCO_2e each), followed by nutrition (17%: 1.8 tCO_2e). One third (32%: 2.4 tCO_2e) of the Japanese footprint originates from housing, followed by mobility and nutrition (20–18%: 1.6–1.4 tCO_2e each). The biggest contributor to the average lifestyle carbon footprint in China is housing (33%), in Brazil, nutrition (37%) and in India, mobility (36%). Consumer goods and leisure and services account for a small proportion (10 ± 3% and 15 ± 5%, respectively) with little variation between case countries.

3.3. Comparing Footprints of Specific Domains

This section elaborates on the average lifestyle carbon footprints by comparing three domains: nutrition, housing and mobility. Other domains (consumer goods, leisure and services) are compared only between Finland and Japan due to limited data for China, Brazil and India. Results of the analysis for each domain are presented beginning with observations for Finland and Japan, followed by China, Brazil and India, and finally as a cross-country comparison.

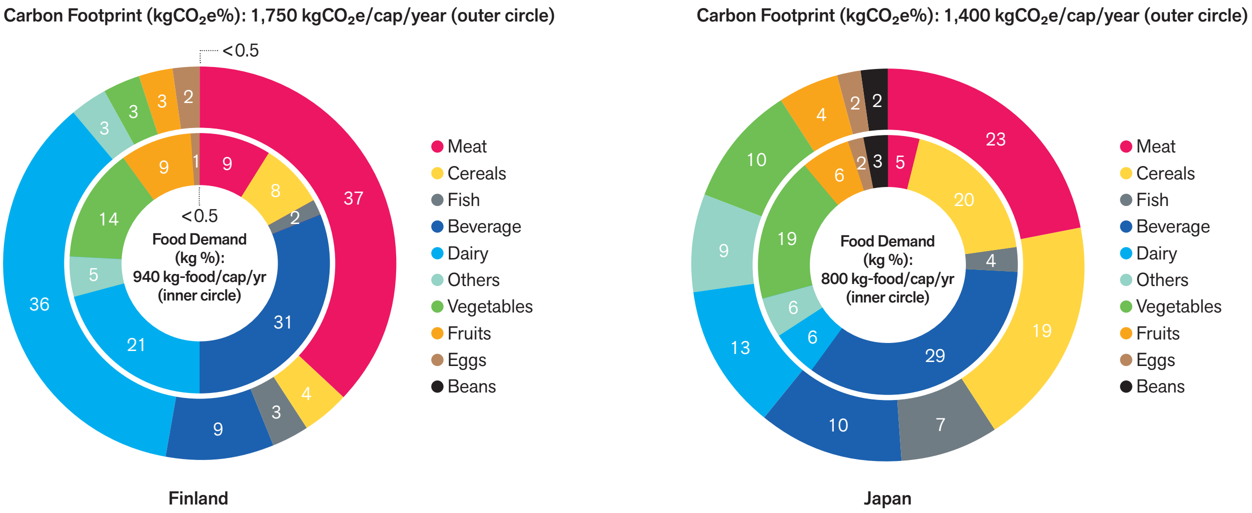
The results are visualised using "skyline charts" for the carbon footprints (Figures 3.4, 3.6, and 3.8), which give amounts of consumption (x-axis) and carbon intensity (y-axis) for the different components. The size of each rectangle thus expresses the total carbon footprint, and the left-right order of the rectangles represents highest-lowest total footprint. In these charts, the average intensity and total consumption in each domain is indicated by dotted grey rectangles, and the 1.5 degree targets for 2030 and 2050 as dotted red and blue rectangles, respectively. Shares of different sub-domains in carbon footprints and physical consumption are shown as donut charts (Figure 3.3, 3.5, and 3.7), where the inner circles represent the share of physical consumption and the outer circles represent the share of carbon footprints.

For specific data sources and details of estimation results, please refer to Annexes B and C, respectively.

1. Nutrition

Finland – The average Finn has a nutrition carbon footprint of 1,750 kg (CO_2e per year), of which meat products comprise over one-third (37%) (see outer circle Fig. 3.3). The highest contributor to this is beef, which, despite its relatively small proportion compared to pork and chicken, has a high carbon intensity contributing 43% to the footprint of meat. Another third of the footprint is caused by dairy products (36%), mostly due to cheese and milk. Beverages produce nearly a tenth (9%) of the footprint due to the carbon intensity of beer and coffee. Fish and egg carbon intensities are relatively high but amounts consumed are low. As a whole, while animal products represent only a third of the physical amounts consumed they have a huge impact (78%) on the

Figure 3.3. A comparison of the share of carbon footprints and physical consumption (nutrition, in % of food demand and % of carbon footprints)



Note: Average lifestyle carbon footprints and physical amount of consumption estimated as of 2017. Inner circles represent the share of physical amount of consumption. Outer circles indicate the share of carbon footprints.

carbon footprint, much higher than plant-based foodstuffs. The estimated food loss at households of 2.4% (Katajajuuri et al. 2014) is accounted for in the food amounts consumed.

Japan – The nutrition carbon footprint of the average Japanese is 1,400 kg (CO_2e per year). For the Japanese too, meat products are a key contributor at nearly a quarter of this footprint (23%) due to their high carbon intensity (see the difference between inner and outer circles in Fig. 3.3), especially beef. Over a tenth (13%) of the footprint is caused by dairy products – the carbon intensity of which highly varies (e.g., butter is 13 times higher than milk). Fish cause 7% of the footprint, and have a high intensity due to relatively high share of non-edible parts supplied to households. Cereals represent nearly a fifth of the footprint, and beverages and vegetables have a tenth each of the footprint, but their carbon intensity is lowish. The carbon intensity of cereals is higher in Japan because of the higher intensity of rice than other crops. Alcohol is over six times more carbon-intense than non-alcoholic beverages. The intensity of Others is also relatively high due to processed or lightweight products such as oils and spices. The food loss in households is estimated as 3.7% (Ministry of Agriculture, Forestry and Fisheries, Japan 2014), which is included in food consumption. Also, the food loss in the supply chain is 4.1% (Ministry of the Environment, Japan n.d.).

China, Brazil, and India – In **China**, meat is heavily consumed, responsible for 44% of an average person's nutrition carbon footprint, with one third of this caused by beef. Fish and vegetables each contribute over a tenth, due to the relatively high carbon intensity of fish and consumption of vegetables. Cereals, rice and wheat combined account for just under a tenth. The average Chinese person's nutrition carbon footprint is 1,050 kg (CO_2e). Meat features nearly as heavily in **Brazil's** nutrition footprint (43%), over half of which is due to beef. Cereals represent a fifth, half of this being due to rice consumption. An average Brazilian has a carbon footprint of 1,040 kg. **India** has a relatively low nutrition carbon footprint, 500 kg, of which three-fifths is due to dairy and cereals, which is mostly caused by rice consumption. Dairy products are mainly based on milk, which has a relatively high carbon intensity.

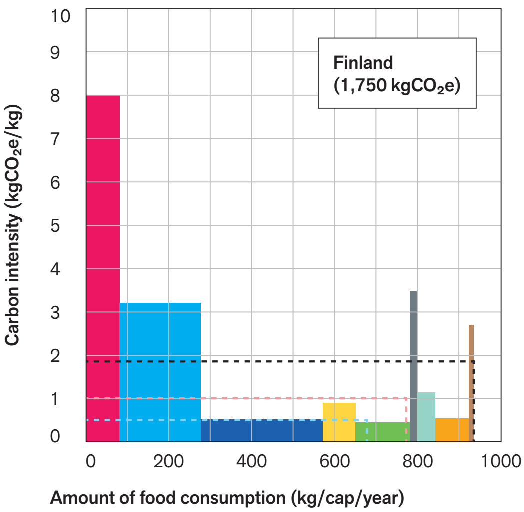
In most of the case countries, meat consumption is the largest contributor to a person's carbon footprint for nutrition, varying across countries – from over 80 kg eaten in Finland to the about 35 kg eaten in Japan, with approximately 45 and 60 kg being eaten in Brazil and China, respectively. In China and Finland, most of the meat consumed is pork (63%, 43%, respectively) and poultry (22%, 29%). India is the exception, where little meat is consumed (under 5 kg), partly due to the predominance of vegetarianism and the fact that just over half of the meat consumed is poultry.

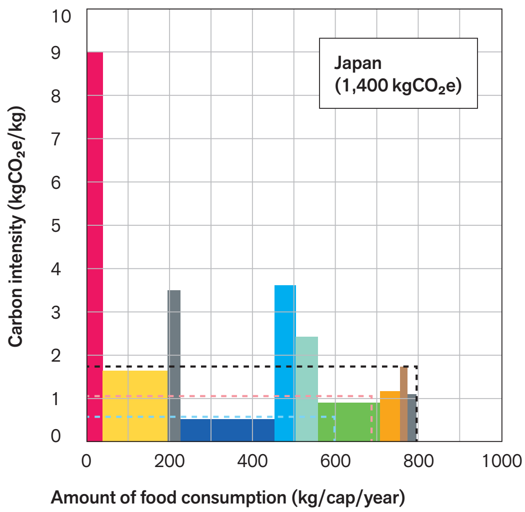
Dairy products are another significant contributor to Finland's carbon footprint, approaching meat, due to the large consumption (almost 200 kg per person) of cheese and other dairy products, whereas Indian, Japanese, and Brazilian people consume much less – about 85, 50, and 35 kg, respectively. Dairy consumption is also trending up in many countries (Food and Agriculture Organisation 2017).

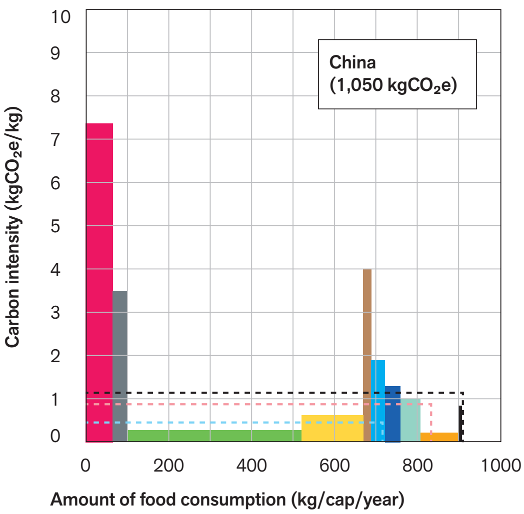
Other major contributors to the nutrition carbon footprint are fish, cereals, and beverages. Fish is a major contributor in Japan and China at 30 to 35 kg consumed per person. Cereals have relatively high carbon intensity in Japan and Brazil, probably due to rice consumption, which tends to have higher intensity than wheat and other cereals. Beans are a relatively low-carbon and protein-rich food and generally have low carbon intensity, but their kg consumption is limited in most of the case countries, with over 20 in Japan, 15 in India, and less than 10 in Finland and China – Brazil is the exception, at 70 kg.

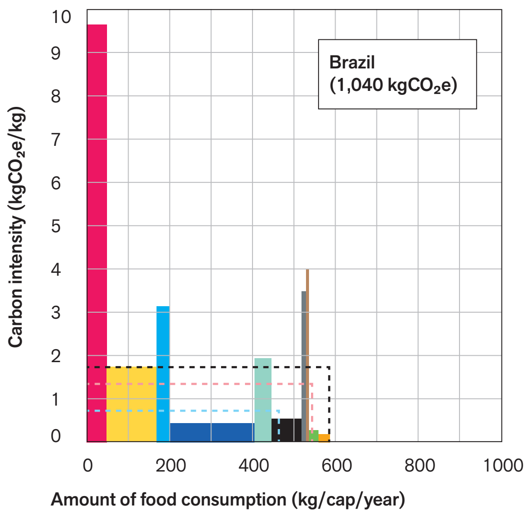
As indicated by the dotted rectangles in Figure 3.4, the nutrition footprints of Finland and Japan need to be greatly

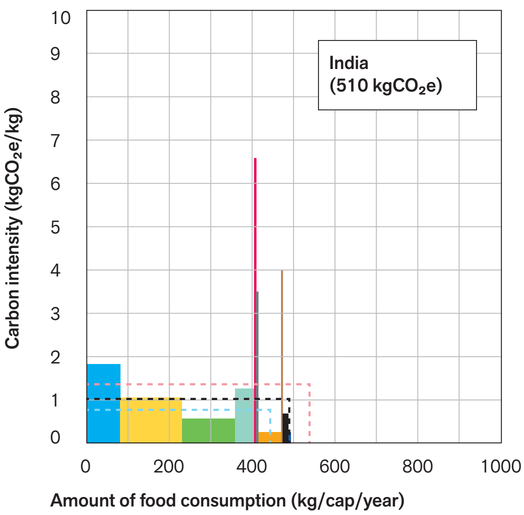
Figure 3.4. A comparison of carbon footprints and their breakdown (nutrition, in kgCO_2e/cap/year 2017)











- - - Average as of 2017
- - - 1.5 degree target by 2030
- - - 1.5 degree target by 2050

● Meat ● Dairy ● Beverage ● Cereals ● Vegetables ● Fish ● Others ● Fruits ● Eggs ● Beans

Note: Coloured rectangles indicate the average lifestyle carbon footprints of each component. Width, height, and size of the area represent the physical amount of consumption, carbon intensity, and carbon footprints, respectively. Black dotted rectangles show the average intensity and total physical consumption as of 2017. Red dotted rectangles show the 1.5 degree target by 2030 and blue dotted rectangles the 2050 target. The horizontal and vertical ratios of the red and blue dotted rectangles are indicateive only. If amounts cannot be reduced, intensity needs to be reduced instead. This can be an issue especially in the nutrition domain as it is considered as essential.

reduced: by 47–58% by 2030 and 75–80% by 2050[10]. Yet, the estimated reduction required is below that of other domains as there is less variation in current footprints, implying nutrition is considered a necessity (see Annex D for more details). Further, China, Brazil, and India would also need to significantly reduce nutrition-related footprints by 2050, and the current per-capita footprints in China and Brazil already exceed the 2030 target. Shifting nutrition sources and reducing carbon intensity or physical consumption amounts where possible while satisfying nutritional requirements can contribute to reducing footprints.

2. Housing

Finland – The average Finn lives in housing with a floor space of 40.3 m², which produces a footprint of 62 kg (CO_2e per m²). Finns use a lot of indoor heating due to the large average living space and long winters. Electricity accounts for a third (34%) of each person's annual footprint of 2,500 kg (CO_2e), including its use as a main heating source, and district heating accounts for nearly two-fifths (38%) as again, a lot is used, and it has a relatively high carbon intensity. The fuels used for district heat production are wood or other biomass, coal, natural gas, peat, waste and oil (Finnish Energy 2016). Heating oil has one of the highest carbon intensities in housing but relatively little is actually used. The share of other forms of energy is relatively high, but the resulting carbon intensity is low as wood is mainly used.

Japan – The average Japanese lives in housing with a floor space of similar size to Finland at 39.4 m², which gives the same carbon emissions figure as Finland of 62 kg (CO_2e per m²). Nearly four-fifths of a person's annual carbon footprint of 2,430 kg is represented by direct energy consumption (77%), over half of which is electricity. Grid electricity is mainly (84%) from coal, oil and LNG, with hydropower and other renewables producing only 15% (Agency for Natural Resources and Energy, Japan 2018). The direct energy supplied to households is comprised equally of electricity and other energy (mainly fossil-fuel based, such as kerosene for heating, and LPG and city gas for cooking and heating), with only less than a tenth (8%) from renewables (discussed later).

China, Brazil and India – The average **Chinese** lives in an area with a footprint of 39 kg (CO_2e per m²). Electricity consumption contributes more than one third to the carbon footprint of housing. Although each person uses a small overall amount of electricity, almost three quarters of it comes from carbon intensive coal- and oil-based thermal power, accounting for nearly a third (27%) of the housing footprint of 1,350 kg (CO_2e) per year. In **Brazil**, the carbon footprint of housing is 22 kg (CO_2e per m²) for an average person, almost half of which results from the relatively carbon-intense living spaces. However, the shares of both energy and electricity are around a quarter each due to low overall consumption and the high use of renewable energy. The annual average housing carbon footprint is 470 kg, or 17%

Electrification of home energy sources should be promoted together with renewable-beased grid electricity.

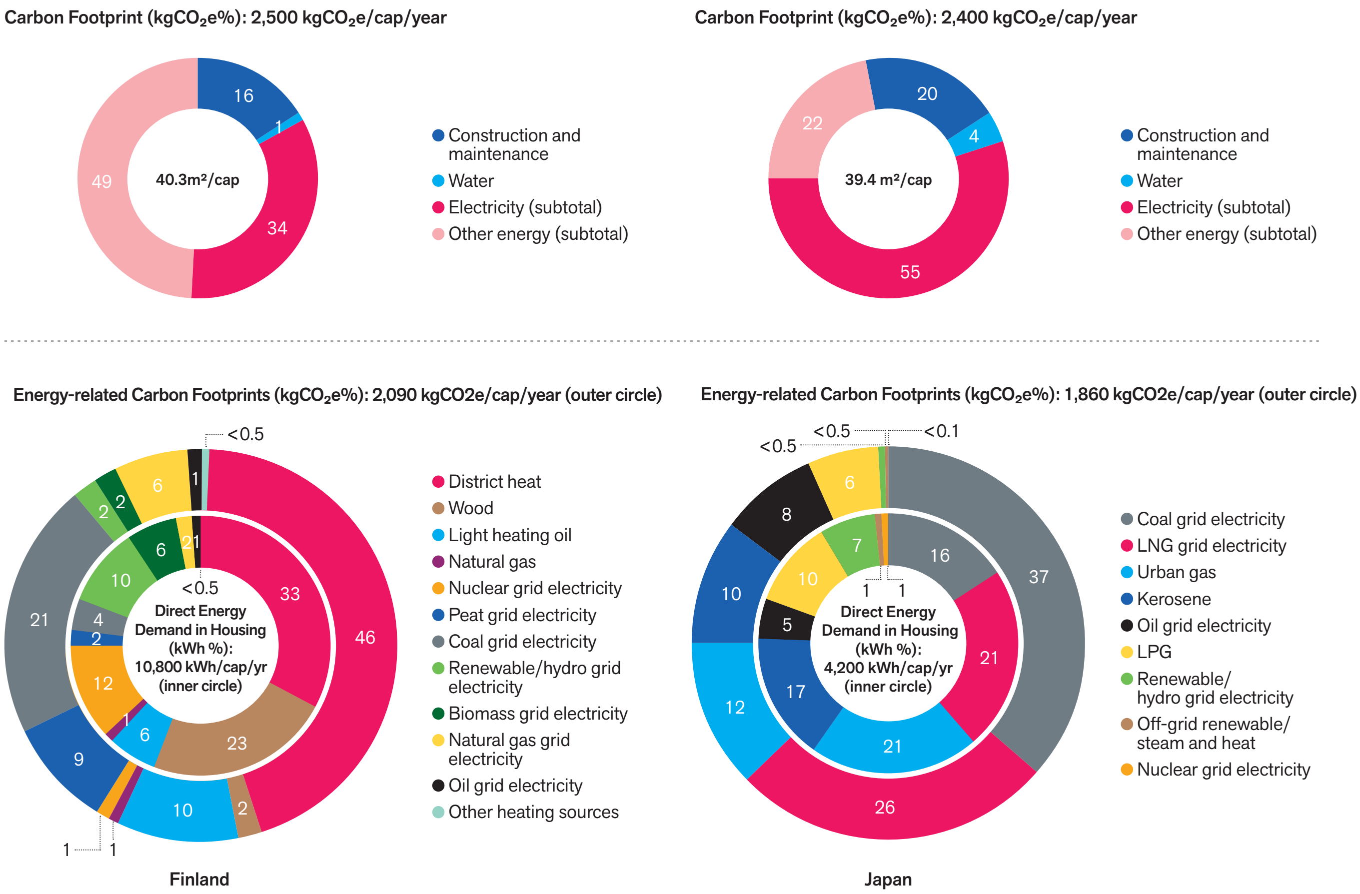
of the total carbon footprint for a Brazilian. The share of both electricity and other energy is approximately 22–25% each, due to low overall consumption and the high share of renewable energy sources. In **India**, housing produces just over a fifth (21%) of the total carbon footprint of an average person, or 21 kg (CO_2e per m²), with nearly half of the emissions (48%) coming from the living space and nearly two-fifths from electricity, due to the high share of non-renewable energy used. The total consumption of other energy forms is higher but the carbon intensity is lower as the main (88%) fuel is firewood for heating. The average Indian has a housing carbon footprint similar to Brazil, at 420 kg.

The two developed countries, Finland and Japan, have similar footprints of approximately 2,400–2,500 kgCO_2e/capita, with a carbon intensity of approximately 60 kg (CO_2e per m²). These countries have similarly sized living spaces of 40 m², with construction and maintenance accounting for up to a fifth (16–20%) of the footprint. However, there are big differences in direct energy use (Finland 10,800, Japan 4,200 kWh), and energy used per living space (Finland 270, Japan 110 kWh per m²). This is partly because of the high energy demand for heating in Finland – 65%, 15% and 5% of domestic energy use is for indoor heating, water heating and sauna heating, respectively. Although Japan has a relatively high demand for hot water use of 29%, indoor heating and cooling only account for respectively 22% and 2% of house energy consumption (Agency for Natural Resources and Energy, Japan, 2017).

Electrification of direct housing energy use with renewables can contribute to low-carbon lifestyles, but fossil-fuel-based electricity can be less efficient in comparison with non-electricity energy sources. Japan has a higher electrification rate of direct energy consumption in the housing domain, with 51% compared to 37% in Finland. Typically, electricity-based room temperature control systems such as heat pumps have higher energy conversion efficiency at the household level. If fossil fuels are used to produce the grid electricity for home heating, it generally has higher carbon intensity than home-heating systems using fossil-fuel based non-electricity energy because the conversion efficiency of power plants is relatively low. Therefore, electrification of home energy sources should be promoted together with renewable-based grid electricity.

10 Comparison with the lower limit of the 2030 and 2050 targets (1.5D scenario)

Figure 3.5. A comparison of the share of carbon footprints and physical consumption (housing, in % of carbon footprints and % of direct energy demand)



Note: Average lifestyle carbon footprints and physical amount of consumption estimated as of 2017. Inner circles represent the share of physical amount of consumption. Outer circles indicate the share of carbon footprints.

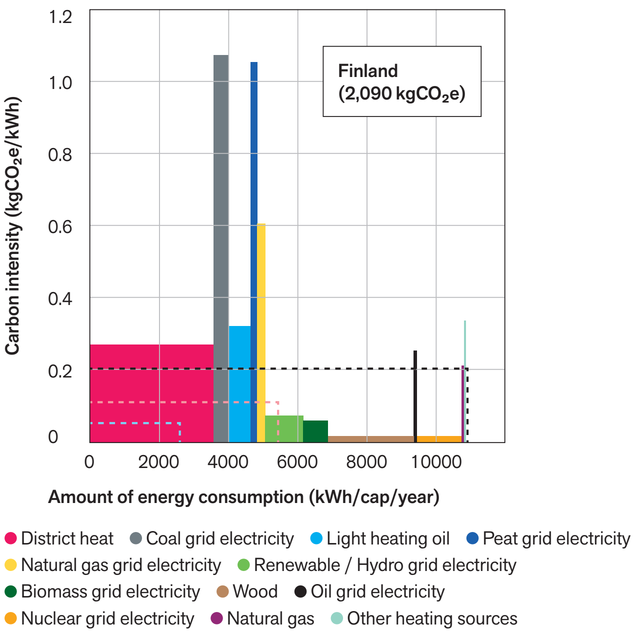
The carbon intensity of grid electricity and non-electricity in Finland is about half of that in Japan (0.19 vs 0.44 $kgCO_2e$/kWh) as nearly half of it (45%) comes from renewables, whereas 84% of Japan's electricity is generated from fossil fuels, nearly a third of which (32%) is coal. For non-electricity energy, Japanese houses typically use LPG and urban gas for heating and cooking, as well as kerosene for heating (49% of overall energy from housing), with off-grid renewables and steam under 1%. On the other hand, 48% of the energy used for room and water heating in Finnish homes is district heat, which has relatively low carbon intensity despite being largely fossil-fuel based, and 34% of energy used for room, sauna and water heating is from wood, which is carbon neutral (except for indirect emissions such as transport and production). As a result, for direct housing energy use, Finland's overall renewable share is higher than Japan's (37% vs. 8%).

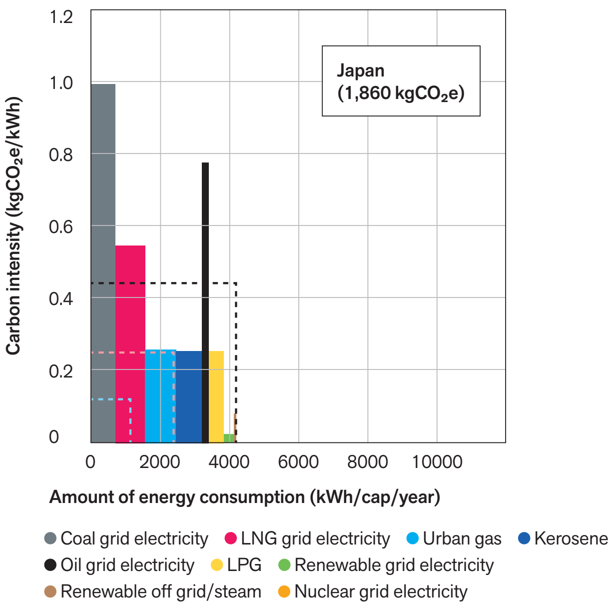
In comparison, the carbon footprint for housing in developing countries is much lower, from 1,350 in China to 400 ($kgCO_2e$) in India, as well as carbon intensity per living space, from 20 to 40 ($kgCO_2e$ per m²). Spaces are smaller per person (35 m² in China, 21 in Brazil, 19 in India), and energy use from housing is low (1,500 kWh in China, 1,400 in Brazil, 800 in India) due to lower heating demand owing to the climate, less use of appliances and electricity, and larger households living in smaller spaces. Compared to Brazil's high share of renewables in total energy demand (38%), that of China and India are much lower, 6% and 5%, where the carbon intensity of grid electricity is significantly higher due to the high share of fossil fuels. In Brazil, 85% of grid electricity is renewables, mainly hydropower. Other energy forms used in China, Brazil and India are mainly coal and derivatives, LPG and firewood, which notably increases the total share of non-renewables in total energy consumption in China and Brazil.

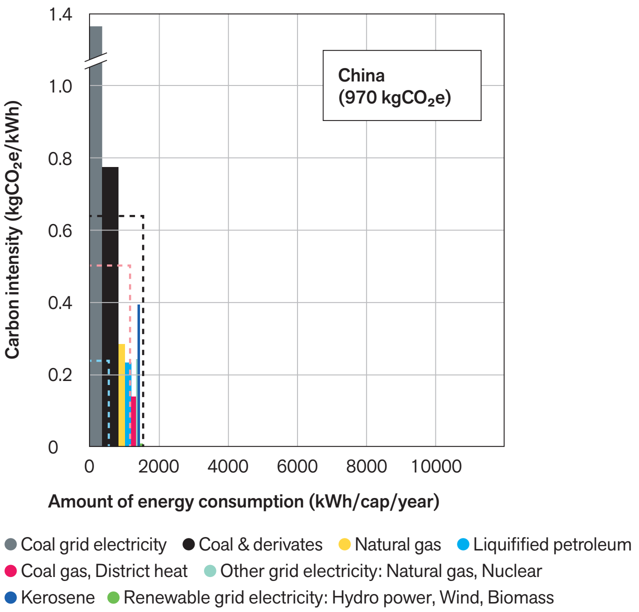
In relation to the 1.5 degree targets for 2030 and 2050, the reductions needed in Finland and Japan are 68–69% and 92–93%, which should be achieved either by reduced consumption or improved efficiency[11]. Looking at the housing energy-related footprints in Figure 3.5, carbon intensity in Japan and energy consumption in Finland both need addressing urgently. Brazil and India are currently within the 2030 target but not the 2050 target, and China already exceeds the 2030 target.

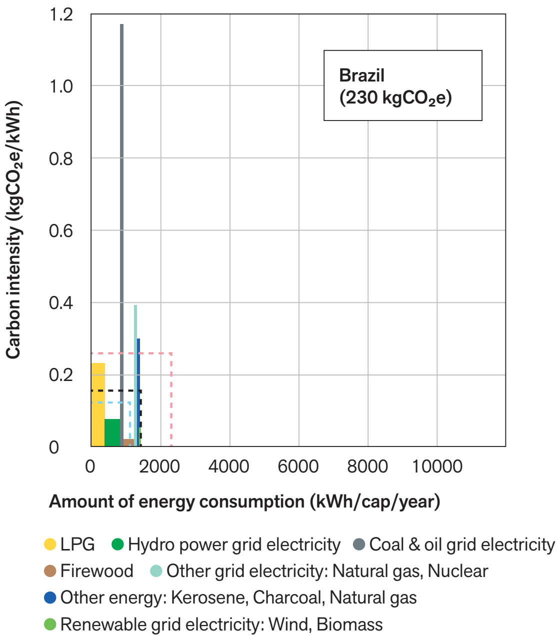
11 Comparison with the lower limit of the 2030 and 2050 targets (1.5D scenario)

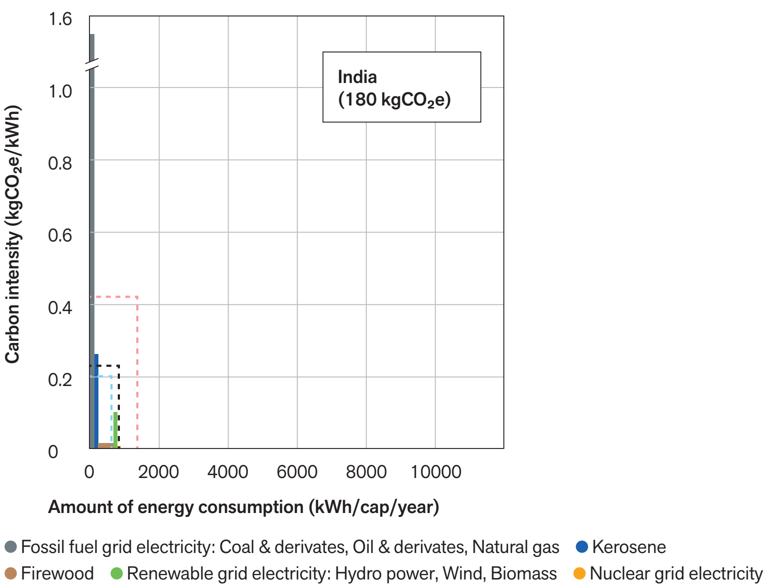
Figure 3.6. A comparison of carbon footprints and their breakdown (housing energy, in $kgCO_2e$/cap/year 2017)

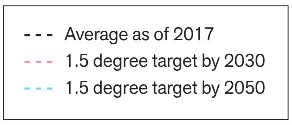












Note: Coloured rectangles indicate the average lifestyle carbon footprints of each component. Width, height, and size of the area represent the physical amount of consumption, carbon intensity, and carbon footprints, respectively. Black dotted rectangles show the average intensity and total physical consumption as of 2017. Red dotted rectangles show the 1.5 degree target by 2030 and blue dotted rectangles the 2050 target. The horizontal and vertical ratios of the red and blue dotted rectangles are indicateive only. If amounts cannot be reduced, intensity needs to be reduced instead.

3. Mobility

Finland – For the average Finn, mobility contributes just over a quarter (27%), or 2,790 kg (CO_2e) of their carbon footprint, over three quarters of which is caused by heavy car use (11,200 km) and its high carbon intensity. Four-fifths of the emissions come from fuel combustion (VTT Technical Research Centre of Finland Ltd 2017), but emissions from vehicle production are also included in the figure. They also travel a lot by air, 2,180 km, or 13% of transport demand, and another 1,640 km (10%) by land-based public transport – over half of which is bus, two-fifths train, and less than a tenth tram or metro. Nine-tenths of the trains (VR Group Ltd 2017) run on renewable energy, giving a carbon intensity just a fraction of that of cars. They also travel 810 km, or 2.2 km per day, on motorcycles, snowmobiles, quad bikes, microcars, and so on, and cycle little, at 260 km, or 0.7 km a day.

Japan – For the average Japanese, mobility contributes just over a fifth, or 1,550 kg (CO_2e) of their carbon footprint and they travel 11,000 km a year, including walking. Nearly four-fifths of their mobility footprint comes from cars, which while representing less than half their annual km travelled (5,000 km), incurs a high carbon intensity, partly due to the low occupancy rate, high share of fossil-fuel use, and low use of hybrid/electric vehicles. Taxis have even higher carbon intensity due to their relatively low occupancy rate. Air travel contributes almost a tenth of the carbon footprint, or 0.09 kg per passenger km, which while less than cars adds up due to relatively long trips (approx. 600 km domestic, 1,000 km international). They also use trains a lot – 3,100 of the 3,600 km land-based public transport demand (with the remainder being buses) – which have very low carbon intensity of 0.02 kg per km. Cycling accounts for only 270 km, or 0.7 km a day.

China, Brazil, and India – These countries have respective mobility shares of a quarter, a sixth and a third of their total carbon footprint. For the average **Chinese**, mobility contributes 1,090 kg (CO_2e), over half of which is due to car use, which as mentioned above is highly carbon-intense, but motorcycles contribute a fair share too. They use public transport the most (in terms of distance), mostly bus, which is more carbon-intense than trains. The average **Brazilian** has a mobility footprint of 480 kg, two-fifths of which each come from cars, due to their carbon intensity, and public transport, due to distances – especially bus. Even with most cars and light vehicles running on ethanol-gasoline blends (flexible-fuel vehicles) (Posada and Façanha 2015), the carbon intensity of car transport is relatively high. The average **Indian's** mobility footprint is 700 kg, nearly half of which is caused by car use due to its high carbon intensity, with motorcycles and public transportation (mainly buses) each accounting for approximately a quarter.

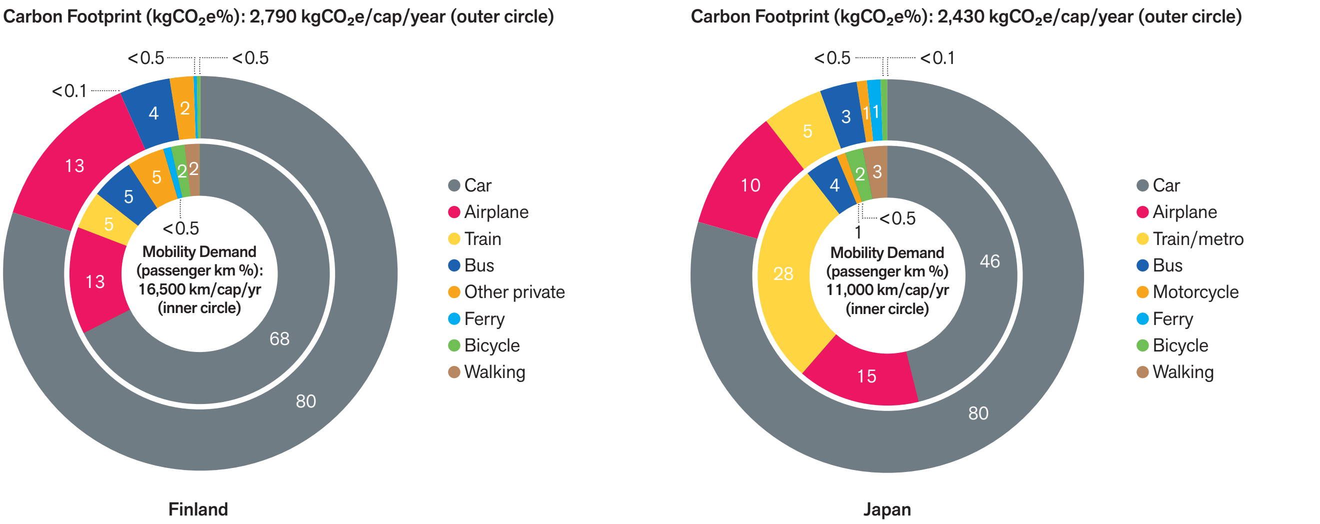
In the cross-country comparison, Finland has the highest mobility demand at 16,500 km, compared with 11,000 km in Japan, and only 4,000 to 8,000 km in Brazil, India, and China.

In the cross-country comparison, Finland has the highest mobility demand at 16,500 km, compared with 11,000 km in Japan, and only 4,000 to 8,000 km in the other three countries. This probably reflects higher population density and metropolitan development in Japan than Finland, with lower consumption levels in developing countries. Of mobility, cars are the biggest contributor to carbon footprint in most case countries, except for Brazil where it is buses. The modal share of cars is very high at 68% (11,200 km) in Finland, moderate at nearly 46% (5,000 km) in Japan, relatively low at 22–27% (1,100–1,800 km) in China and Brazil, and much lower at 15% (800 km) in India. The carbon intensity of cars is slightly higher in Japan than Finland. Carbon intensity is much higher in developing countries such as China and India, partly because of lower fuel efficiency of the cars but also the selection of intensity data, which is based on global averages for different car classes and fuel types.

Air travel is the second largest contributor to the footprints in the two developed countries. In Finland, flights induce 370 kg (CO_2e/capita) while only accounting for nearly 2,200 km (13%) of mobility demand. In Japan, flying contributes 160 kg and also only accounting for low distance, less than 1,700 (15%) of mobility needs. Flights contribute more to carbon footprint in Finland than Japan partly due to the higher intensity of flights with lower occupancy rates[12].

12 Occupancy rate is 53 to 73% (Lähteenoja, Lettenmeier, and Saari 2006), which is slightly lower than 69 to 83% in Japan (All Nippon Airways 2018; Japan Airlines 2017).

Figure 3.7. A comparison of the share of carbon footprints and physical consumption (mobility, in % of passenger km and % of carbon footprints)



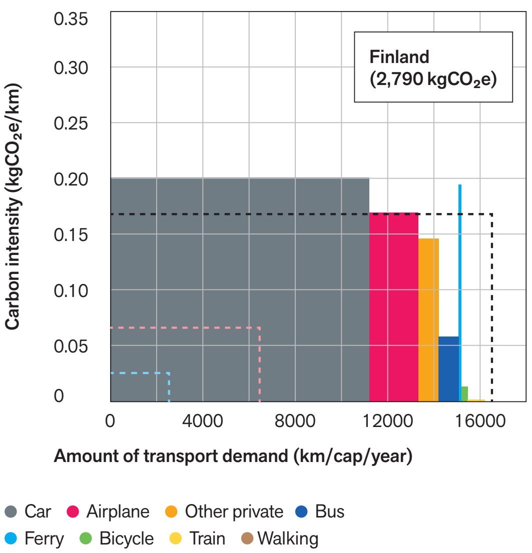
Note: Average lifestyle carbon footprints and physical amount of consumption estimated as of 2017. Inner circles represent the share of physical amount of consumption. Outer circles indicate the share of carbon footprints.

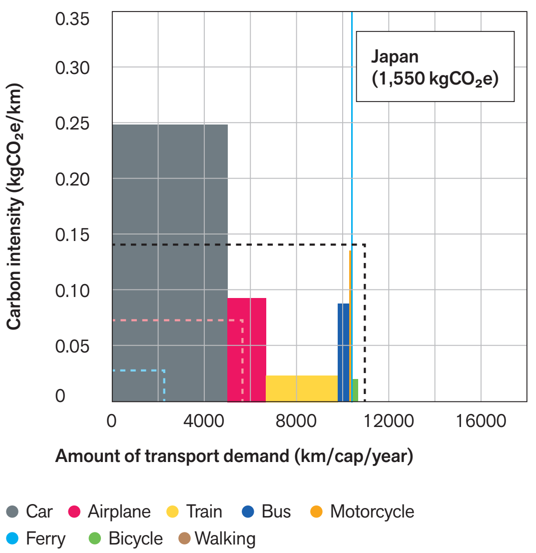
Land-based public transport is used more in Japan than Finland (33%, 3,600 km vs 10%, 1,640 km), partly reflecting the higher service coverage supported by high population density. Japan has a higher share of trains (28% of mobility demand) than Finland, but both countries use buses to similar extents (5% in Japan, 6% in Finland). Trains have relatively low carbon intensity (0.02 kg) in Japan but are almost zero intensity in Finland due to the carbon-neutral policy of the national train service (VR Group Ltd 2017). Land-based public transport is used more in developing countries (31–49% in Brazil, China, and India) and serves for nearly half of mobility demands in Brazil. In these countries, trains are less used (6–7%), while buses play a higher role (24–43%). In China, motorcycles are used more (over 20%), and although they have lower carbon intensity than cars, it is still much higher than public transport. Cycling is highest in China and India (1,100 km, 500 km), and low in other countries, lower than around 250 km.

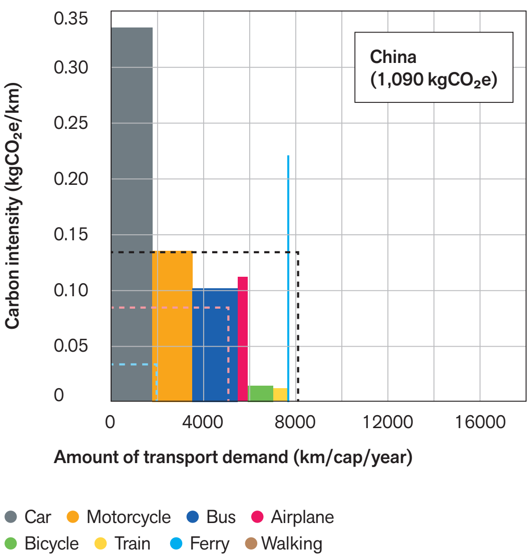
In relation to the 1.5 degree targets for 2030 and 2050, the reductions needed in Finland and Japan in mobility are 72–85% and 96–98%, respectively[13]. These reductions are much larger than for other domains due to the higher variation in current footprints, implying a higher possibility to reduce them (see Annex D for more details). The current footprints for China, India, and Brazil already exceed the 2030 target, which implies the urgency of starting the low-carbon shift in mobility systems and consumption patterns in these countries.

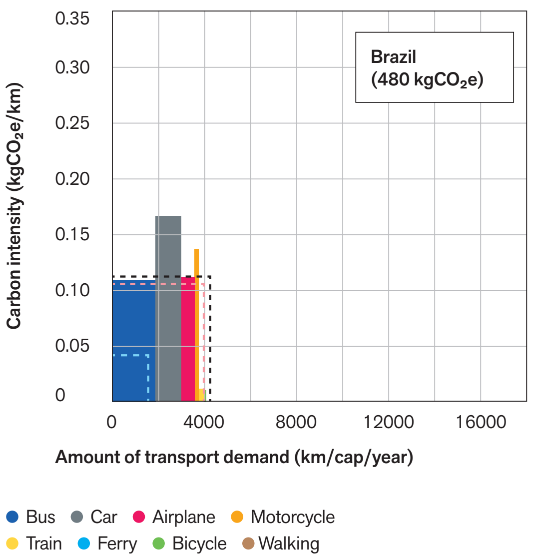
13 Comparison with the lower limit of the 2030 and 2050 targets (1.5D scenario)

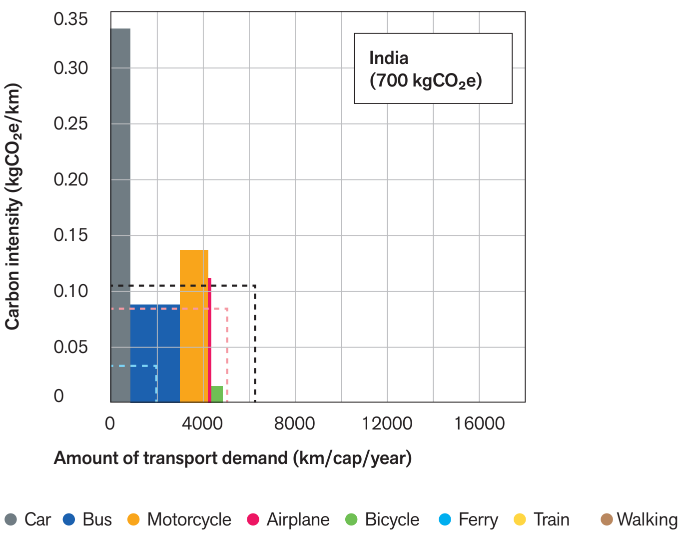
Figure 3.8. A comparison of carbon footprints and their breakdown (mobility, in $kgCO_2e$/cap/year 2017)

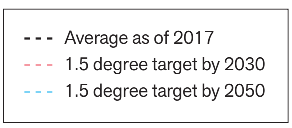












Note: Coloured rectangles indicate the average lifestyle carbon footprints of each component. Width, height, and size of the area represent the physical amount of consumption, carbon intensity, and carbon footprints, respectively. Black dotted rectangles show the average intensity and total physical consumption as of 2017. Red dotted rectangles show the 1.5 degree target by 2030 and blue dotted rectangles the 2050 target. The horizontal and vertical ratios of the red and blue dotted rectangles are indicateive only. If amounts cannot be reduced, intensity needs to be reduced instead.

4. Other domains (consumer goods, leisure, and services)

Finland – Detailed data or product lists concerning total amounts and carbon intensities of consumption in domains of household goods, leisure and services was not publicly available so the related carbon footprints are based on the study by Seppälä et al. (2009). The carbon footprint of consumer goods is 1,330 kg (CO_2e/capita), which is 13% of Finland's average lifestyle carbon footprint. Mixed goods and services related to furnishing and housekeeping (categorised under furniture) account for the greatest share of consumer goods (360 kg), followed by clothes, outdoor equipment (categorised under sport/entertainment) and mixed products and services (ranging from 240 to 270 kg each). ICT/AV equipment (110 kg) and paper products/stationery (90 kg) are minor contributors. Leisure-related products and services (recreational and cultural services, 180 kg; travel expenses abroad, 200 kg; and hotel services, 200 kg) together accounted for only 570 kg (CO_2e/capita) (6% of the total carbon footprint), and the impact of this domain is therefore minor. Services accounted for 1,480 kg, which is 14% of the average annual lifestyle carbon footprint in Finland. Healthcare, social services, and education-related services are the largest contributors in this domain, with 590, 460, and 220 kg (CO_2e/capita) respectively, or 85% of the service domain's footprint.

Japan – Consumer goods account for 1,030 kg (CO_2e/capita), or 13% of the average person's lifestyle carbon footprint in Japan. Home appliances and ICT/AV equipment are the largest contributors at nearly a third (320 kg (CO_2e/capita), or 31%), with clothing second, representing a fifth (220 kg, or 21%). Apart from daily essential consumables such as sanitation (120 kg) and other items (160 kg), entertainment and luxury products are also a major contributor, e.g., sports and entertainment tools, jewellery, and tobacco accounts altogether for almost 150 kg, or 14%.

Leisure services consumed outside the home account for 580 kg (CO_2e/capita) of the lifestyle carbon footprint, with in particular two-fifths and one-fifth coming respectively from restaurants and hotels[14]. The monetary equivalent carbon intensity for hotel and restaurant services including the footprint induced from food ingredients is over 0.3 kg (CO_2e) per 100 JPY, the highest among leisure items. Amusement facilities and racing stadiums, including for legal gambling, as well as nightlife and bars contribute 165 kg (CO_2e) (30%), and these leisure items have a relatively high carbon intensity at 0.25 kg per 100 JPY. The rest of the 40 kg footprint is accounted for by cultural, sports, and outdoor leisure including movies, theatre plays, sports facilities, and outdoor parks, which have relatively low carbon intensities per monetary value of under 0.20 kg per 100 JPY. Access to these leisure facilities is accounted for in the mobility domain.

The average Finn has a slightly higher footprint than the average Japanese from consumer goods (1,330 vs. 1,030 kgCO_2e), possibly due to slightly more spending (over 3,000 EUR in Finland compared to yen equivalent of 2,800 EUR) and slightly higher carbon intensity in Finland than Japan (0.44 vs. 0.36 kg/Euro). Note that consumer goods data is not directly comparable – Finnish data is derived from product groups based on the Classification of Individual Consumption by Purpose (COICOP) and thus cannot be split further, and goods data might include some products or services that would be classified differently in Japanese data. For leisure services, both countries have a similar carbon footprint of 600 kg per capita, but Japan has a higher footprint from restaurants and hotels (380 kg, over 60%), while the distribution of the leisure footprint in Finland is broader: recreational and cultural activities, consumption during travel abroad, and hotel services. Data for Japan does not include consumption during travel abroad, and this data is not directly comparable due to different estimation methodologies.

The Japanese carbon intensity data implies that the shift from material purchases to leisure and experience consumption may not immediately contribute to low-carbon lifestyles. On average, the carbon intensity per unit of monetary value for consumer goods and leisure services is almost the same (0.29 kg per 100 JPY) including the footprint induced from food ingredients, which implies that shifting expenditure from material-based consumption to experience- or service-based consumption may not immediately reduce carbon footprints to the extent that low-carbon leisure activities or low absolute amounts of goods consumption would. Non-leisure service consumption accounts for approximately 650 kg per capita in Japan, with a slightly lower carbon intensity of 0.15 kg per 100 JPY, partly reflecting the labour-intensive and less material-intensive characteristics of the service industry.

14 Excluding the footprint derived from food ingredients, which is reflected in the nutrition domain.


4

4. Options for Reducing Lifestyle Carbon Footprints

This chapter examines the reduction potentials of low-carbon lifestyle options towards meeting the 1.5-degree target, based on the estimates for current lifestyle footprints and proposed per-capita targets. First, key approaches concerning low-carbon lifestyles are explained before evaluating country-specific impacts of low-carbon lifestyle options that could be applied, after which the aggregated impacts of low-carbon options are estimated.

4.1 Key Approaches for Low-carbon Lifestyles

This study estimates lifestyle carbon footprints based on the amount of consumption and the carbon intensity of the items. The report adopts three main approaches for reducing these amounts: absolute reduction, modal shift, and efficiency improvement (Fig. 4.1). These approaches are in line with analysis and recommendations from related literature (Jones and Kammen 2011; Vandenbergh, Barkenbus, and Gilligan 2008; Lacroix 2018). 'Absolute reduction' (Akenji et al. 2016) refers to reducing the amount of consumption as opposed to raising environmental efficiency. It is sometimes labelled as 'sufficiency' (Figge, Young, and Barkemeyer 2014). In this study, absolute reduction refers to reducing amounts of physical consumption but not necessarily expenditure. 'Modal shift' (Nelldal and Andersson 2012) is typically discussed for transportation, but in this study we expanded it to incorporate other domains such as food types and energy sources and call it 'consumption mode'.

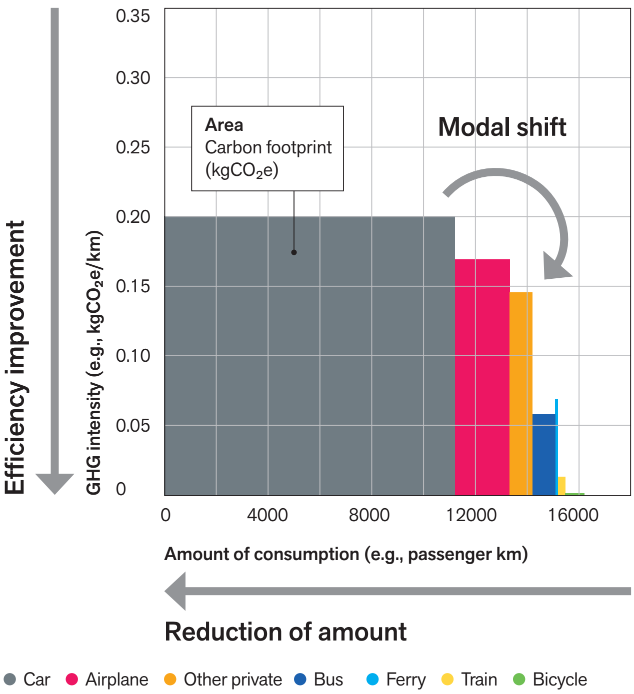
Absolute reduction means reducing physical amounts of goods or services consumed, such as food, kilometres driven, energy use, or living space, as well as avoiding unsustainable options.

Efficiency improvement means decreasing emissions by replacing technologies with lower-carbon ones while not changing the amount consumed or used, such as in energy-efficient agriculture, vehicles, or housing.

Modal shift means changing from one consumption mode to a less carbon intensive one, such as in adopting plant-based diets, using public transport, or renewable energy for electricity or heating.

In the context of introducing efficient products or environmentally sound behaviours, consideration of rebound effects is essential. Rebound effects refer to "the unintended consequences of actions by households to reduce their energy consumption and/or greenhouse gas (GHG) emissions" (Sorrell 2012). Rebound effects have been discussed in the context of efficiency improvements, warning of the risk that efficiency improvements might increase total consumption and even increase emissions by making consumption cheaper (Schmidt-Bleek 1993a). A review study on the rebound effect of energy consumption concluded that direct rebound effects (rebound in the same consumption item) are expected to be up to 30%, while indirect and economy-wide rebound effects (rebound in other consumption items) can exceed 50% (Sorrell 2007). For example, introducing fuel-efficient cars might increase the total distance travelled by cars or the size of cars, which could potentially upset or

Figure 4.1. Key approaches for lifestyle carbon footprint reduction: absolute reduction, modal shift, and efficiency improvement.



Note: The above is an example from Finland's mobility domain.

even reverse the absolute amount of resource use or emissions. Recently, rebound effects have also been considered in the context of other approaches including modal shift or absolute reduction (Buhl 2014; Ottelin, Heinonen, and Junnila 2017). Although there are some single product or behaviour solutions which contribute to reducing environmental impacts, it is important to examine cross-domain household behaviours as a package to consider rebound effects.

Although theoretically the sharing economy can bring about significant synergies with low-carbon lifestyles (see box "Circular Economy and Low-carbon Lifestyles"), it also involves the possibility of rebound effects, depending on the options chosen (see Clausen et al. 2017 for its potential negative effects). For example, car-sharing might increase the total distance of car use among citizens who were previously car-free, and increase car use especially outside rush-hours, thus potentially weakening demand for public transportation. Sharing options thus should not raise total carbon footprints by inducing additional demand or causing unexpected adverse shifts in consumption modes.

Another important factor is the "lock-in" effect (Akenji and Chen 2016; Sanne 2002). In facilitating low-carbon lifestyles, consideration of behavioural "lock-in" is important. While technological and institutional lock-in have been discussed in the context of blocking sustainable innovations, hence a stalemate leading to "carbon lock-in" of the current unsustainable industrial economy (Foxon 2002; Unruh 2000), lock-in also applies to consumer choices and lifestyles in terms of products on the market, infrastructure, the consumer's community (Akenji and Chen 2016), as well as by economic framework conditions (Lorek and Spangenberg 2014). Rather than being keen and willing to consume more, consumers in the current society are locked-in by circumstances including work-and-spend lifestyles (Sanne 2002). Considering these perspectives, there is a need to improve production processes, increase the supply of low-carbon products or services by the private sector, and bring about a shift in infrastructure as well as introduce more national policies in order to realise many options. Therefore, to avoid consumer scapegoatism, the shift in lifestyles is not the sole responsibility of consumers based on their individual choices (Akenji 2014), and requires collaborative action by all the stakeholders, especially the private sector and the government.

Circular Economy and Low-carbon Lifestyles

Recently, 'circular economy' has been discussed as a strategy contributing to low-carbon society (Material Economics 2018), and involves shifting from "a linear model of resource consumption that follows a 'take-make-dispose' pattern" to "an industrial economy that is restorative by intention; aims to rely on renewable energy; minimises, tracks, and eliminates the use of toxic chemicals; and eradicates waste through careful design" (Ellen MacArthur Foundation 2013). Circular economy can also contribute to low-carbon lifestyles. The 3Rs can offer opportunities for low-carbon solutions through more efficient use of materials. The circular economy can contribute to low-carbon lifestyles through the key approaches discussed above, through sharing models such as ride sharing and co-housing to promote better efficiency through greater use of buildings and vehicles. Sharing can also enable modal shift by offering new solutions for everyday travel in the mobility sector. Reduction of food loss in both supply and consumption can also be realised via circular strategies, such as sustainable, more efficient food production chains. Circularity also can help make low-carbon options resource-efficient, e.g., the material footprint of electric cars can be higher than for fuel-based cars (Frieske et al. 2015) but increasing the use of recycled materials for batteries and other metals could reduce material footprints (Teubler, Kiefer, and Liedtke 2018). As discussed in the main text, the low-carbon synergy of sharing options may vary depending on the types of options and the extent of rebound effects.

4.2 Estimating Impacts of Low-carbon Lifestyle Options

Both demand- and supply-side measures can contribute to reducing global GHG emissions in line with the targets proposed in Chapter 2. In this study, the impacts of carbon footprint reduction were estimated for selected low-carbon lifestyle options in Finland and Japan.

Strategically identified and promoted impactful carbon reduction options are essential in addressing the Paris Agreement target as the reductions required towards 2030 and 2050 are not incremental but drastic (e.g., over 60–70% reduction by 2030). Given that both government and educational materials often fail to address this and instead focus on incremental or otherwise low-impact issues (Wynes and Nicholas, 2017), it is important to consider lifestyle options which have large reduction potentials in each domain.

In order to identify the low-carbon lifestyle options, we reviewed the current literature to reveal: what options were recommended with a focus on those related to production and consumption; those offering different approaches of reductions (absolute reduction, modal shift, efficiency improvement); and those with sufficient impact.

As a result, we identified approximately 50 low-carbon lifestyle options across four domains (nutrition, housing, mobility, and consumer goods). The reviewed literature includes Project Drawdown (Hawken 2017), Capital Consumption (Hersey et al. 2009), Sitra's Green to Scale (Tynkkynen 2016, 2015), Salo and Nissinen (2017), and Sitra's 100 options for smart and sustainable living (Finnish Innovation Fund Sitra 2017) and their background materials[15].

The footprint reduction impacts of low-carbon options would depend on the country. The reviewed literature contains quantified reduction impacts but mostly in a specific context of a country or city and some of the quantification is based on emissions but not footprints. In this study, we estimated country-specific impacts of selected options for Finland and Japan based on the collected data on physical consumption amount and intensity (see Chapter 3). The reduction impacts were estimated based on the collected consumption and footprint data by changing the intensity and/or amount of relevant components depending on the nature of the options.

The percentage of the population who will change their behaviours and the extents each individual goes to are critical when estimating impact, thus we show different adoption rates in this study. "Full implementation", as it suggests, means individuals fully implement the low-carbon option and generate maximum reduction potentials. "Partial-adoption" means the options are partially adopted, either by individuals or at the society level. The "full implementation" practices of each option are defined as assumptions listed in Annex F, and the resulting maximum reduction potentials were estimated using the collected carbon footprint data by changing the intensity and/or amount of relevant components. Impacts from "partial-adoption" were estimated based on the following equation:

Partial adoption impacts
= full implementation impacts x adoption rate (%)

> The reductions required towards 2030 and 2050 are not incremental but drastic.

The results of the estimated carbon footprint reduction impacts from full and partial implementation of options are summarised in Figures 4.2 and 4.3. It should be noted that the selected low-carbon lifestyle options and their assumptions slightly differ between countries due to the applicability of options to local contexts and availability of data.

The common options in both countries with the largest reduction potential of **500 to over 1,500 kg *per option*** on average[16] are **car-free private travel[17], renewable grid electricity, electric cars, vegetarian diets, renewable off-grid energy, hybrid cars, and vehicle fuel efficiency improvement**. For Finland they also include **vegan diets and heat pumps for temperature control**. Most options are based on a modal shift from carbon-intensive to other low-intensity consumption modes, such as car to public transport, fossil fuel to renewable energy, and meat to vegetarian nutrition sources. Efficiency improvement options such as vehicle fuel efficiency and electric and hybrid cars are also listed. The majority of these most impactful options are from the mobility and housing domains, while food also has potential impacts through shifting dietary habits.

Options with the next largest reduction potentials of **250 to 500 kg *per option*** on average[18] are **ride sharing, living closer to workplace, heat pumps for temperature control, car-free commuting, alternative dairy products, low-carbon protein instead of red**

15 More detailed methodology and review results are included in Annex E.

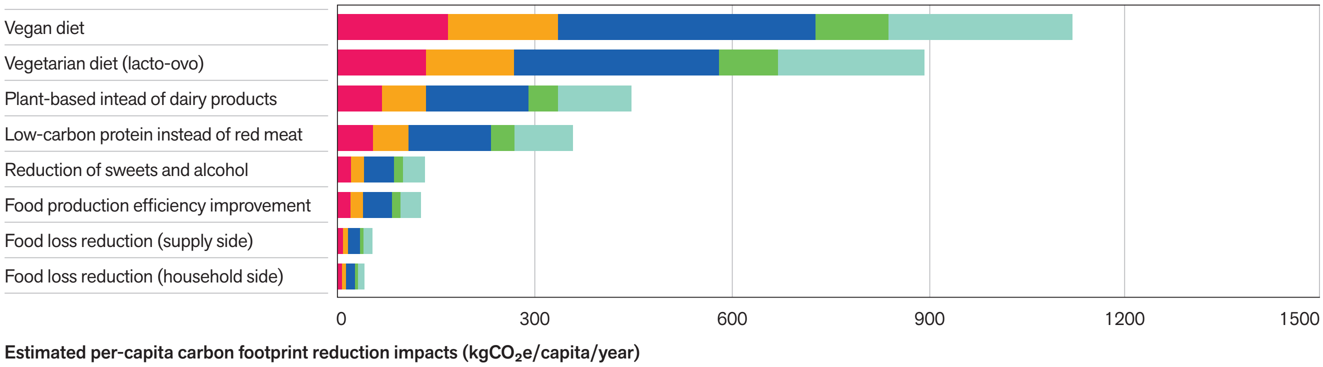
16 Estimated to have more than 500 kgCO_2e/capita/year reduction potential in full implementation as a mean of potentials in two case countries. Descending order by estimated mean reduction potentials.

17 Shift of transportation mode from private cars to public transport for the private purpose trips such as leisure and visiting shops. Commuting is excluded from this items but included in another specific item.

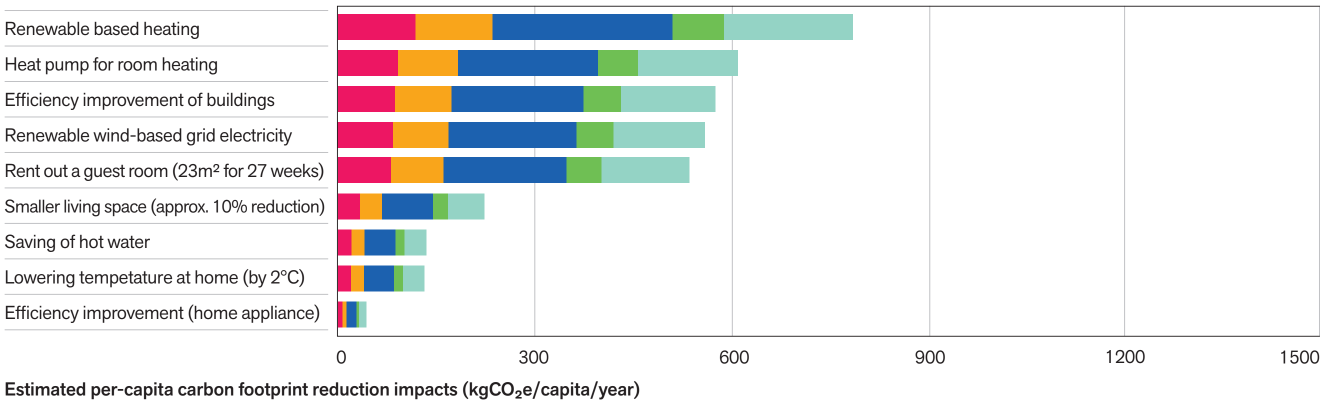
18 Estimated to have more than 250 kgCO_2e/capita/year reduction potential in full implementation as a mean of potentials in two case countries. Descending order by estimated mean reduction potentials.

Figure 4.2. A comparison of the estimated per-capita carbon footprint reduction impacts of low-carbon lifestyle options (Finland)

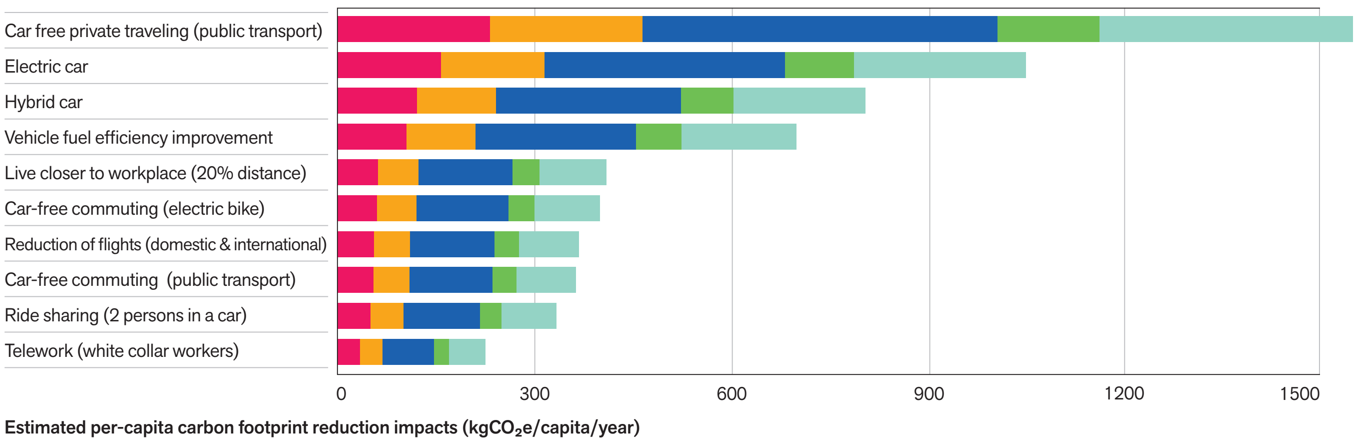
a) Nutrition, Finland



b) Housing, Finland



c) Mobility, Finland

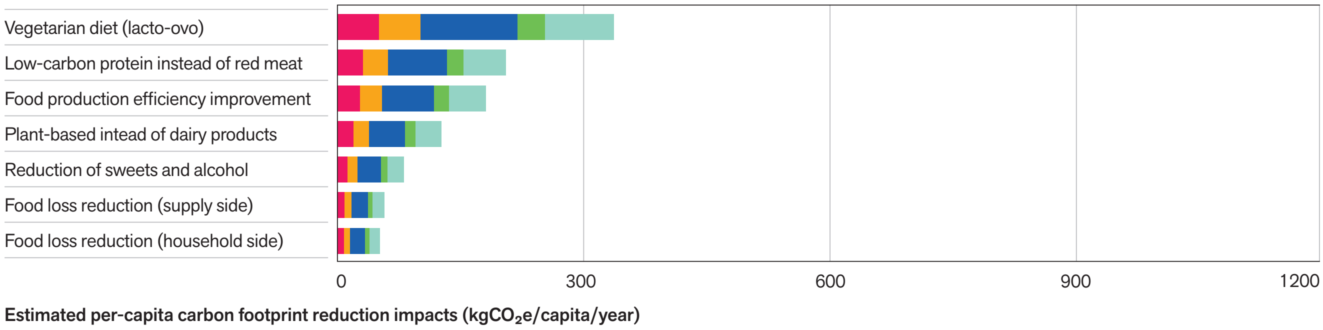


● 15% adoption rate ● 30% adoption rate ● 65% adoption rate (2S target) ● 75% adoption rate (1.5D target) ● 100% adoption rate

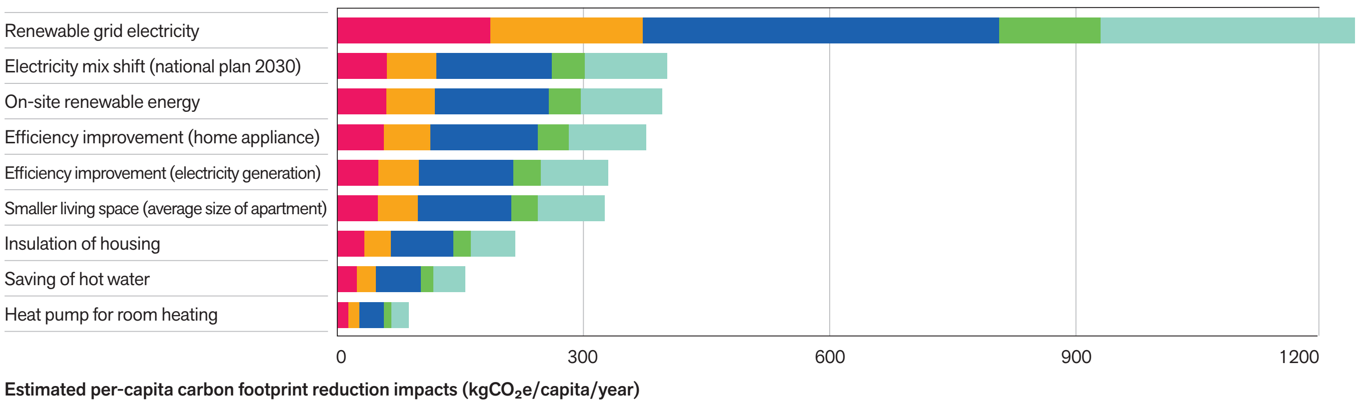
Note: Estimated by authors based on the assumptions in Annex F. Sum of individual reduction impacts are not equal to aggregated impacts in Tables 4.1 and 4.2 due to overlaps and synergies between options.

Figure 4.3. A comparison of the estimated per-capita carbon footprint reduction impacts of low-carbon lifestyle options (Japan)

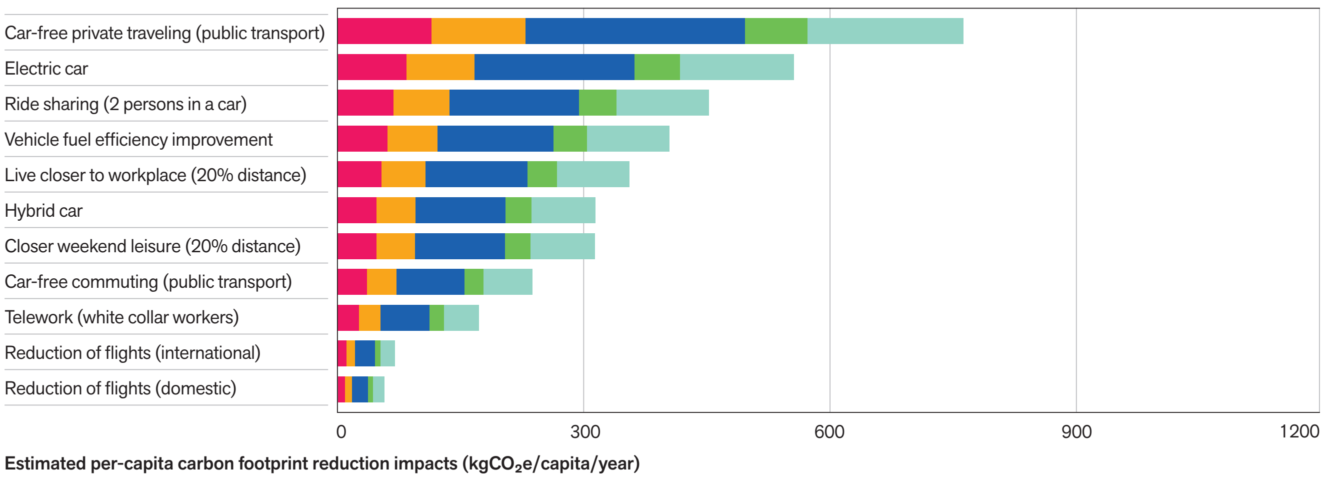
a) Nutrition, Japan



b) Housing, Japan



c) Mobility, Japan



● 15% adoption rate ● 30% adoption rate ● 65% adoption rate (2S target) ● 75% adoption rate (1.5D target) ● 100% adoption rate

Note: Estimated by authors based on the assumptions in Annex F. Sum of individual reduction impacts are not equal to aggregated impacts in Tables 4.1 and 4.2 due to overlaps and synergies between options.

meat, and smaller living spaces. Some of the otions which are only included for one country, such as renting a room to tourists, electricity generation efficiency improvement, and closer weekend leisure are also evaluated to have the same range of reduction potentials. Some options include an absolute reduction approach such as reducing commuting distance, and others based on a modal shift approach such as shifting transportation mode and dietary habits. The options cover all three major domains of mobility, housing and nutrition.

The options with moderate impacts, less than 250 kg per option on average[19], are efficiency improvement of home appliances and production of food, telework[20], saving of hot water, reduction of flights, reduction of food loss and excess food, i.e., options based on efficiency improvement of production and products or absolute reduction of physical consumption amounts.

Tables 4.1 and 4.2 give the aggregated impacts from introducing all low-carbon lifestyle options, and are based on the assumption that all options have the same adoption rate (e.g., 15%, 30%). Evaluating aggregated impacts are necessary because sums of estimated reduction impacts of individual options may not agree with aggregated impacts due to overlaps and synergies between options. In Finland, adoption rates of 15% and 30% of all selected options will reduce lifestyle carbon footprints by 27% (or 2.9 tCO_2e/capita/year) and 43% (or 4.5 tCO_2e/capita/year), giving total lifestyle carbon footprints of 7.6 and 5.9 t, respectively. In Japan, the same gives reductions of 18% (1.4 t) and 34% (2.6 t) in the footprint, with estimated lifestyle carbon footprints after introducing the options of 6.2 and 5.1 t, respectively[21].

The adoption rates of the selected options towards meeting the targets proposed in Chapter 2 were then identified, revealing that a rate of 75% for all selected options was required to meet the targets of 1.5 °C without or with less use of CCS (2.5 t by 2030), and 65% for 2 °C targets with use of CCS (3.0 t by 2030). In Finland, these adoption rates can reduce lifestyle carbon footprints by 70% and 77% (7.4, 8.0 t), and in Japan, by 62% and 68% (4.7, 5.2 t), respectively. At the 100% adoption rate[22], aggregated impacts are reductions of 87% (9.1 t) in Finland and 79% (6.0 t) in Japan. Based on this theoretical maximum adoption rate, lifestyle carbon footprints end up at 1.4 t and 1.6 t in Finland and Japan, respectively, which approach the higher range of the 2050 target (1.4 to 1.5 t with use of CCS).

The aggregated reduction potentials show that very ambitious adoption (both on consumption and production sides) of low-carbon options (over 75%) across all consumption domains is necessary to achieve the 1.5 degree target. This will reduce lifestyle carbon footprints of average individuals in Finland and Japan to 2.5 t, the proposed 1.5 °C target by 2030. Also, even to achieve the 2 °C target, an ambitious introduction, such as an adoption rate of 65%, is still required. Given that the target for 2050 is much lower, at 0.7 to 1.0 t, the options listed in this study cannot satisfy this long-term target, and additional options including non-incremental changes in provision systems and lifestyles would be required. These results highlight the large potential lifestyle changes required across consumption domains in order to implement the Paris Agreement, and also imply it is not an either-or question of technology or lifestyles but rather both – improvements to the energy system and technology as well as shifts in consumption patterns are required to achieve the ambitious climate targets.

Regarding the limitations of this study, first, the estimation of reduction potentials is limited in terms of coverage. Options were selected based on a literature review (see Annex E) and are not exhaustive, and the study does not consider completely new, innovative low-carbon options in the future, which are not yet prominent in the existing literature. Second, the estimates are based on relatively simplistic assumptions of changes in consumption amounts, modes, and/or carbon intensity, as well as the production side adopting the most ambitious company targets (see Annex F). Also, changes in energy systems such as renewable electricity grid mix were not systematically reflected in the estimation of every product and service but only as a specific option of direct energy use in the housing domain and as a general efficiency improvement in production in other domains – such energy system changes can be studied in future research. Further limitations relate to estimation of aggregated impacts, which do not consider the rebound effects. Therefore, this estimation should thus be considered as slightly optimistic, as some of the gains from options are expected to be lost through re-spending of money and time. Last, this study does not consider the dynamic changes towards the future such as interactions between demography, technology, economy, and consumption or comparisons with business-as-usual scenarios. The estimated impacts were simply calculated by altering amounts of consumption or carbon intensity of components based on the estimated footprints as of 2017, while the targets indicated for comparison relate to the future, such as 2030. A more precise, dynamic modelling of future lifestyles is beyond the scope of this study.

19 Estimated to have less than 250 $kgCO_2e$/capita/year reduction potential in full implementation as a mean of potentials in two case countries. Descending order by estimated mean reduction potentials.

20 Footprints caused by business operation such as energy consumption at office building is considered as part of production activities and attributed to each product or service consumed, but commuting is considered as part of household final demand. Thus, telework and shifting commuting transportation mode were included in this study as low-carbon options.

21 In this calculation, the reduction impacts in percentage can be larger than adoption rates. The size of reduction impacts depend on the selection of options and the definition of full implementation of each low-carbon option. Some options have large reduction potentials, and combination of them can derive larger reduction potential in percentage than adoption rates.

22 For domains other than nutrition, housing, and mobility, 90% reduction of total footprint in each domain was assumed.

Table 4.1. Aggregated reduction impacts of low-carbon options (Finland)

	15% adoption	30% adoption	65% adoption (2S target, 2030)	75% adoption (1.5D target, 2030)	100% adoption (90% for goods, leisure and services)
Reduction of footprints in each domain ($kgCO_2e$%)					
Nutrition	−25%	−43%	−67%	−70%	−74%
Housing	−45%	−56%	−77%	−82%	−92%
Mobility	−28%	−48%	−74%	−78%	−87%
Goods	−15%	−30%	−65%	−75%	−90%
Leisure	−15%	−30%	−65%	−75%	−90%
Services	−15%	−30%	−65%	−75%	−90%
Average	−27%	−43%	−70%	−77%	−87%
Total Footprints ($kgCO_2e$/capita/year)					
Total reduction	−2,860	−4,510	−7,350	−7,990	−9,060
Footprint after reduction	7,570	5,920	3,080	2,430	1,360

Note: The same adoption rate is assumed to be applied to all options listed in Figures 4.2 and 4.3. The footprints of consumer goods, leisure, and services were assumed to be uniformly reduced by the same percentage as adoption rates, except for 100% adoption rate where reduction for these domains were set as 90%.

Table 4.2. Aggregated reduction impacts of low-carbon options (Japan)

	15% adoption	30% adoption	65% adoption (2S target, 2030)	75% adoption (1.5D target, 2030)	100% adoption (90% for goods, leisure and services)
Reduction of footprints in each domain ($kgCO_2e$%)					
Nutrition	−11%	−20%	−40%	−44%	−54%
Housing	−20%	−37%	−64%	−69%	−78%
Mobility	−28%	−48%	−73%	−77%	−85%
Goods	−15%	−30%	−65%	−75%	−90%
Leisure	−15%	−30%	−65%	−75%	−90%
Services	−15%	−30%	−65%	−75%	−90%
Average	−18%	−34%	−62%	−68%	−79%
Total Footprints ($kgCO_2e$/capita/year)					
Total reduction	−1,410	−2,590	−4,650	−5,190	−6,030
Footprint after reduction	6,230	5,060	2,990	2,460	1,620

Note: The same adoption rate is assumed to be applied to all options listed in Figures 4.2 and 4.3. The footprints of consumer goods, leisure, and services were assumed to be uniformly reduced by the same percentage as adoption rates, except for 100% adoption rate where reduction for these domains were set as 90%.


5

5. Conclusions

The objective of this study was to analyse and demonstrate the extent to which lifestyles contribute to greenhouse gas emissions and to the problem of climate change. In interpreting the results of the analysis, the report then offers opportunities for pursuing a sustainable society, including by reducing individual carbon footprints with a view to meeting the 1.5 °C aspirational target under the Paris Agreement for climate change. Focusing on two developed countries, Finland and Japan, as well as the broader global context represented by Brazil, China, and India, it reveals patterns and characteristics of lifestyle carbon footprints of households based on physical amounts of consumption and the carbon emissions they cause. By comparing present amounts with future limits, as represented by the 1.5 degree Paris target, the report shows where potential opportunities lie for lifestyle changes over the long term, as well as gaps and hotspots over different countries.

Long-term Targets for Lifestyle Carbon Footprints

This study proposes **long-term targets for lifestyle carbon footprints comparable with the 1.5 °C aspirational target of the Paris Agreement as 2.5, 1.4, and 0.7 tCO_2e per capita for 2030, 2040, and 2050**, respectively, based on representative mitigation pathways drawn from scientific literature assuming no or low use of negative emission technologies. They are proposed as globally unified equitable per capita targets for the carbon footprint of household consumption at the national average level. Meeting them requires changes in lifestyles of individuals and households and, of equal importance, implies systemic changes in infrastructure and provision systems via governments, businesses and other stakeholders. If negative emission technologies such as CCS and BECCS are considered, this raises the upper limits of the targets to 3.2, 2.2, and 1.5 tCO_2e per capita in 2030, 2040, and 2050, respectively – in other words their use greatly affects the target limits. However, the long-term availability and costs of such technologies are uncertain, and solely relying on the assumed massive application of negative emission technology is a risky strategy with potentially misleading consequences. Thus, this study provides mitigation pathways that do not assume maximum use of negative emission technology in the future.

In terms of inter-country differences in targets, the five case countries revealed huge gaps. The 10.4 and 7.6 tonne carbon footprints of Finland and Japan need to be reduced by **80–93% by 2050, assuming that actions for a 58–76% reduction (a 8–12% reduction every year from 2019 to 2030) start immediately to achieve the 2030 target. Any delays in starting actions would mean that per capita targets would increase and thus long terms targets would become even tighter**. For developing countries, the current carbon footprints of 4.2 tonnes in China, 2.8 tonnes in Brazil and 2.0 tonnes in India need to be reduced by **23–84%, depending on the country and the scenario, by 2050**. These gaps reveal the urgency of immediate and massive action in developed countries, and for emerging economies to find alternative paths with low-carbon infrastructure and provision systems that enable sustainable lifestyles as the primary option.

Hotspots of Lifestyle Carbon Footprints

The examination of lifestyle carbon footprints based on physical consumption units revealed several hot-spots of lifestyle areas, such as meat and dairy consumption, fossil-fuel based energy, as well as car use, which are currently the major causes of climate change from the perspective of household consumption. These hot-spot areas can be impactful intervention areas for activating low-carbon lifestyles compatible with the Paris Agreement.

Out of the consumption domains considered, **nutrition, housing, and mobility tend to have the largest impact (approximately 75%) on total lifestyle carbon footprints**, and these areas therefore offer high potential for impactful intervention. In the nutrition domain, even small shares of meat and dairy consumption cause remarkable shares in footprints. In contrast, the consumption of beans, vegetables, and fruits, which are low carbon but can be nutritious food items, is relatively small. In the housing domain, fossil-fuel based electricity, such as from coal and LNG, and non-electricity fossil fuel use are major contributors to the footprints. The share of renewable energy is limited except for wood in Finland. In the mobility domain, the high share and intensity of private car use is the largest contributor to footprints, followed by flights, while limited use of public transport and bicycles was identified.

Based on the domain-specific gap analysis with the targets, **the range of footprint reductions required for the developed countries for 2030 (2050) are at least 47% (75%) in nutrition, 68% (93%) in housing, and 72% (96%) in mobility**. This overshoot is not only about the developed countries; put another way, current footprints of developing countries analysed for this report already exceed the 2050 target in all domains, and mobility-related footprints already exceed the 2030 target.

The analysis also identified large differences in current consumption patterns, footprint contributors and mitigation potentials between countries, which is due to differences in consumption levels and carbon intensities of products and services. To illustrate, country-specific hot-spots include dairy consumption and amount of total energy consumption in Finland and fossil-fuel based electricity in Japan. On the other hand, car-driving and meat consumption are significant hot-spots in all countries, except for meat consumption in India. As each country has a unique culture and society, consumption patterns and mitigation potentials from lifestyle changes are expected to vary. This implies that, even if we establish per-capita unified targets for lifestyle carbon footprints at the global level by 2030 and 2050, solutions should be tailored to each context while still addressing the urgent and massive need for change.

Opportunities for Low-carbon Lifestyle Options

This study identified low-carbon lifestyle options spanning many domains, and estimated per-capita lifestyle carbon footprint impacts of approximately 30 options each for Finland and Japan. **The options with potentially high impact include: car-free private travel and commuting, electric and hybrid cars, vehicle fuel efficiency improvement, ride sharing, living closer to workplaces and in smaller living spaces, renewable grid electricity and off-grid energy, heat pumps for temperature control, vegetarian and vegan diets, and substitution of dairy products and red meat**. These are not the entirety of options for reaching 1.5-degree lifestyles but rather the most promising ones for which data was available and among those analysed. In practice, any concerted attempts to meet the set targets would need a substantial expansion of these options, and inclusion of radical reductions options.

For those analysed in this report, if fully adopted, the annual reduction potentials of each option span from several hundred kg to over a tonne of carbon dioxide equivalent. To illustrate, if adopted extensively, the reduction potential of car-free private travel is over 1,500 kg CO_2e in Finland and 700 kg CO_2e/capita/year in Japan, and renewable electricity has the potential to reduce over 500 kg CO_2e/capita/year in Finland and

The range of footprint reductions required for the developed countries for 2030 are at least 47% in nutrition, 68% in housing, and 72% in mobility.

1,200 kg CO_2e/capita/year in Japan. Also, the shift to a vegetarian diet has a reduction potential of approximately 900 kg CO_2e/capita/year in Finland and over 300 kg CO_2e/capita/year in Japan. Other options such as efficiency improvements in home appliances and food production, teleworking, saving hot water, reducing flights, reducing food loss, and reducing excess food consumption also demonstrate moderate reduction impacts on the level of average consumption. With some specific individuals or certain sectors of population, these options can still reveal even higher reduction potential.

These low-carbon options are based on both consumption and production measures, and include the **three key approaches: absolute reduction, modal shift, and efficiency improvement**. Very large potentials were estimated, especially for modal shift, for example in terms of diet, energy, and transportation. Moderate to high potentials were also demonstrated through reduction of physical consumption, such as mobility distance by teleworking and living closer to workspaces, and improvements of efficiency, such as of vehicles and home appliances. Such **shifts in consumption modes, substitution of products to improve efficiency and reduction of physical consumption amounts while maintaining quality of life can only be achieved through a combination of system-wide changes and a groundswell of action from individuals and households**. The availability of products and infrastructure are essential in enabling citizens to shift to low-carbon consumption modes, especially regarding high-impact options. Therefore, while citizen and consumer decisions are important, it is critical that pro-sustainability choices are enabled by ensuring that infrastructure and institutions facilitate viable and accessible options compatible with 1.5-degree lifestyles. This suggests the need for a concerted effort that involves new governance systems and radical policy shifts, changes in business operations and provisioning systems, and engagement from civil society organisations to shift societal norms and expectations in order to facilitate co-creation and acceptability of new and sustainable ways of living.

The evaluation of aggregated impacts of the selected low-carbon lifestyle options in Japan and Finland reveal that very ambitious 65–75% adoption rates of around 30 options is required to reduce lifestyle carbon footprints towards 2 °C (with CCS) and 1.5 °C (without or with limited CCS) targets by 2030, respectively. If we consider the 2050 target, an even greater variety of low-carbon lifestyle options and even more progressive measures in provision systems would be necessary. The **results imply urgency in developing and providing viable and attractive solutions including low-carbon products and services and the design of infrastructure supporting low-carbon solutions in parallel with facilitating behaviour changes of citizens**.

Some practical implications of the study

This study demonstrates the usefulness of understanding lifestyle carbon footprints and the potential impacts of lifestyle changes on climate change mitigation. It also underscores the importance of further incorporating lifestyle perspectives into the research and discussions related to the Paris Agreement. The literature review revealed emission scenarios and solutions related to climate change often rely on technological solutions, including negative emission technology and production-side efficiency improvements (see Chapter 1 and 2). In this study we present a different perspective, through showing, given the level of footprint reduction required (e.g., 80–93% reduction by 2050), how important it is to adopt low-carbon lifestyle options based on modal shift and absolute reduction.

These low-carbon options should not be construed as merely restrictive measures, but instead as opportunities for new business, employment, and improved quality of life. Many of the low-carbon options, such as reducing excess nutrition intake, use of bicycles, closer leisure destinations and telecommuting have additional knock-on benefits too – such as improved health, exercise, and more free time – synergies which need to be investigated further through future research and interventions.

Actions by all related stakeholders are needed to bring about the level of reductions in footprints as given in this study; the roles of governments and business are essential in shifting infrastructure and ensuring product and service availability, while citizens should be better incentivised to adopt low-carbon lifestyle options as soon as possible, as outlined below.

National and local governments can improve public transport and promote cycling through low-carbon city planning, as well as facilitate switching the energy supply system to renewables. Taxation, subsidies, and other policy instruments can be used to incentivise low-carbon lifestyles: e.g., modal shifts and service accessibility directed at low-carbon solutions and reductions in carbon intensity and consumption amounts for all consumption domains.

Businesses can help increase numbers and types of low-carbon options in the different domains studied, such as for teleworking, platforms for sharing and food loss reduction, alternatives to meat and dairy products, and other decarbonised product and service options. They also need to incorporate 1.5-degree business models into their strategic planning and investment decisions. To facilitate actions by governments and businesses, both the voting and purchasing power of citizens can demonstrate the urgency of initiating systemic changes to bring about absolute reductions, modal shifts, and efficiency improvements, especially in the domains of mobility, housing and nutrition, according to the options presented in this report.

Citizens themselves have, despite being partly locked into solutions provided by existing infrastructure, numerous opportunities to shift their consumption habits, even in the short term – such as in mobility, by shifting to public transport, cycling, and low-carbon vehicles, reducing private car use and use of air travel; in housing, by purchasing, investing or producing renewable electricity, investing in low-carbon houses and equipment such as heat pumps and insulation; and in nutrition by adopting plant-based diets and reducing consumption of meat and dairy, and food waste. Choosing decarbonised products and services, wherever available, is crucial for strengthening the market for low-carbon solutions, as well as for demonstrating interest in low-carbon solutions to local and national government.

Next steps

The study proposed and analysed **lifestyle carbon footprints, defined as the GHG emissions directly emitted and indirectly induced from household consumption**. The methodology developed for this study can be extended to analyse other elements of planetary boundaries than just climate change – looking at, for example, freshwater use and biogeochemical flows such as nitrogen from a lifestyles perspective. With further adaptation, such analysis could be carried out for the sustainable development goals, analysing, for example, resource use and waste from different lifestyles.

As further steps, the estimation of lifestyle carbon footprints and hot-spot analysis can be expanded to other countries not included in this study or to sub-national levels, such as cities. Additionally, carbon footprints of governments and capital investments can also be integrated in the analysis to capture other aspects of society. Such analysis can also be done at the individual level through an interactive lifestyle carbon footprint assessment tool or based on survey data or collected big data on consumer behaviour. In addition, more varieties of low-carbon lifestyle options should be included and evaluated, incorporating specific considerations of local culture, consumer behaviours, and characteristics of infrastructure and service providers. To facilitate the research and ensure comparability, methodological guidance for lifestyle carbon footprint estimation can be developed further as an addition to the present guidelines for footprints of products and organisations.

The targets and understanding of hot-spots and mitigation potentials of lifestyle-related options should be reflected in all strategies of companies and local and national governments over both the short and long term. A dynamic strategy development tool, based on the approach used in this study, to highlight the real impacts of current patterns of consumption as well as estimated impacts of adopting different context-specific options for low-carbon lifestyles can support such strategy development. Options that show promising impacts can be tested with real households, neighbourhoods and cities to better understand feasibility, acceptability and potential for high adoption rates. A combination of research and experiments would further facilitate policymaking, business development, and individual actions towards 1.5-degree lifestyles.

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This report fills a gap in the existing research by establishing global targets for lifestyle carbon footprints. It proposes globally unified per capita targets for the carbon footprint from household consumption in the years 2030, 2040 and 2050. Current average carbon footprints of Finland, Japan, Brazil, India and China are estimated and compared to the targets. The report identifies options for reducing lifestyle carbon footprints and assesses the impact of such options in the context of Finland and Japan. It concludes with suggestions and implications in terms of how to proceed towards lifestyles compatible with 1.5 °C target.

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